SUSTAINABLE WATER USE IN BUILT ENVIRONMENT-

A CASE STUDY OF UNIVERSITY CAMPUS

By

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DEDICATED

TO

MY PARENTS, FAMILY

AND

TEACHERS

ACKNOWLEDGEMENTS

This acknowledgement will hardly justify my sense of profound veneration for my revered supervisor Dr. Muhammad Irfan for his indelible help, unprecedented enthusiasm, constructive criticism and perceptive encouragement. I sincerely thank Dr. Rafiq Muhammad Choudhry for his valuable suggestions, thoughtful criticism and sustained encouragement during pursuance of my master program.

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(Saqib Naveed Cheema)

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ABSTRACT

The ever growing population demands more buildings, greater infrastructure which in turn demands more use of resources. This growing use of resources causes depletion of the current energy and water reserves. Pakistan in the global context stands amongst one of the most water stressed nations and if the current water usage pattern continues, it would be amongst the water scarce nations by year 2030. The depleting water resource is an alarming situation for the entire nation. The growing infrastructure increases the amount of run-off water along with increased demand of water supply. Sustainable construction practice is a way to address the environmental, economical and social issues with significant focus on water efficiency. In order to assess the water savings by water conservation a framework has been developed to identify means and methods for reclamation of storm water. A case study of university campus is selected to assess the impact and contribution of water reuse on fresh water savings. The campus complex is divided into smaller zones based on their functionality and varying surfaces. Each zone is evaluated for the amount of rain and storm water generated using the rational method to calculate the runoffs. The result confirmed that storm water management can facilitate significant fresh water saving. The study in the end proffered the measures to reuse the non-potable water by efficient technology and human behaviour.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The Construction industry plays a significant role in the energy and water consumption of any nation. The high demand of Energy and Water resource by the construction industry is depleting the country's current reserves at an alarming rate but unfortunately the development work for new infrastructure is hard to avoid. Asia alone involves around 44 million people being added to the population of cities every year, to put this in perspective, each day a further 120,000 people are added to the populations of Asian cities, requiring more construction (Roberts and Kaneley 2006). Subsequently, scarcity of potable water is quickly becoming a serious issue as many countries around the world face severe shortages and compromised water quality. Even the states that have been able to address most of the issues are still at a risk: the impacts of climate change, highly unsustainable water use patterns which lead to ground water depletion. The Ground Water table of twin cities (Rawalpindi and Islamabad) is depleting at an alarming rate of ten feet per year majorly due to the large number of authorized and un-authorized Tube wells (Haq et al. 2007). Secondly the increased construction activity is covering the virgin land with impervious surfaces which does not allow the water to penetrate and recharge the ground. The water requirement is on a continuous rise and concurrently the level of ground water is falling, which clearly means that the extraction is done at a rate much faster than the rate of ground water recharge. Construction industry has a lot to contribute to this miserable condition. Means and strategies need to be suggested to conserve water to meet at least non potable requirement by non potable means. For this purpose, National University of Science & Technology (NUST), Islamabad campus is selected as a case study to assess the savings of potable water by use of Rain, Storm and Grey water. The idea of selecting NUST as a case study is primarily because of size and diversity in infrastructure. Spread on an area of 706 Acres of land, NUST offers residential, institutional, health and sports facility connected with roads and filled in spaces with green landscape. NUST water supply system is primarily based on Tube wells and Municipality supply which in coming time would become less efficient and may not be able meet the desired needs of the people and the built environment.

1.2 SIGNIFICANCE OF THE STUDY

An alarming depletion of the ground water and water reservoir at Tarbela Dam is a wake-up call for the authorities and the people of Islamabad. Construction industry however with its significant use of water can play a major role in the rescue by adopting efficient water use strategies. The research is not just to identify the authoritative measures but to change public mind set towards the use of water and energy through technologies and human response. The study would identify strategies for efficient energy and water use to counter the current depleting condition of the state reserves.

Rain, Storm and Grey water can be a useful way of meeting water demand in emergency situations. The re use of all these forms of water require a treatment depending upon the type of reuse. This not only helps cut down the use of potable water but also limits the amount of water flowing into the drain, ultimately cutting down the cost for waste water treatment. The Reclaimed water can meet various non-potable water demands like toilet flushing, car washing and landscaping.

1.3 PROBLEM STATEMENT

The unpredictable weather pattern and growing human need has led to water shortage in various times of the year and floods at the other time. It is about time to realize the importance of good water management. As per United Kingdom's Government commission Stern Review of 2006 estimate; current level of green house gas emission will lead to a rise in global temperature of 2-5 degrees Celsius sometime within next twenty to fifty years. One of the major consequences amongst climate change is less predictable weather pattern with many hotter summers, which are likely to lead to water shortage (H.M. Treasury 2006).

Construction industry by the virtue of its work contributes in producing green house gases directly and indirectly along with uncontrolled use of water.

Sustainable means of construction needs to be adopted to redefine the use of energy, water and production of un-wanted waste. The campus of National University of Science and Technology covering an area of entire sector of Islamabad is still under construction. This means an increased use of resources and water reserves not just during construction but largely at operations stage. The study gives us an opportunity to identify the advantages of water re use strategies in saving the potable fresh water.

1.4 OBJECTIVES

Following are the identified objectives for this research work:

1. To develop a Framework for Water Reclamation Strategies in Built Environment.
2. To evaluate the savings on potable water by using non-potable water.
3. To provide a guideline for achieving sustainable water management in infrastructure development.

1.5 SCOPE OF THE THESIS

The scope of this study is limited to the National University of Science and Technology campus H-12 Islamabad, and the development work in it. The reason to select this particular site is the size and scale of the area of research. The site is no less than a big housing scheme or a small city with all basic amenities, so the research results can be used as role for urbanized area and towns; secondly the closeness to the researcher due to time and resource constraint. The stake holders to the research include Architects, Engineers, Contractors, Builders, Water & Sanitation authorities and Community.

1.6 STRUCTURE OF THE THESIS

The thesis is divided into five chapters. Chapter 1 presents an introduction to Sustainability and Water Use Efficiency. The significance of the study in relation to the national need have been discussed. It also includes the objectives and scope of this research study. Chapter 2 covers the thorough literature review of Sustainable and Green Construction principles for building projects. The basic fundamentals have been elaborated and gap is analysed with reference to the environment in the current scenario. Chapter 3 describes the research methodology adopted for collection of the data and strategy for analysis. Chapter 4 discusses the statistical analysis and results of the survey conducted. It is then followed by the discussion based on analysis and results. Chapter 5 summarizes the main conclusion and recommendations formulated for Sustainable Construction and Water Use Efficiency in a Built Environment.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The human intervention in whatsoever manner has always had an impact on the Earth's environment. Today, everywhere we hear about the global warming, droughts, floods, ever rising energy prices and fresh water shortage. Climate change has been a source of discussion on global media for past many years and according to the department of Communities and Local government; even if we stop producing carbon dioxide right away, there would still be significant climate change over next forty years as a result of past human activity resulting in less predictable climate and water supply (DEFRA 2007). The growing human need has resulted in more buildings, industries, vehicles, factories which are continuously adding to the immense use of natural resources. These natural resources are consumed at a rate much faster than the rate of production. In past, this debate was mostly focused on the industrial and transportation sector only, but energy usage patterns and its associated impacts have become a major issue in the construction industry (Glavinich 2008). According to United States Department of Energy; commercial and residential buildings alone uses 40% of the US annual energy (USEIA 2007). It is not just the problem of developed nations but the developing nations are also adding equally to the depletion of earth resources. There was a time that these issues were considered someone else's problems and far too early to consider them but they are hitting us right here right now. As a result; need for environment friendly buildings, use of alternate energy and water reclaim has increased. Building owners, Architects and Builders should work together for a more efficient outcome. They should adopt the principles of *Green* construction which is not only good for the environment but for their business too.

2.2 SUSTAINABLE DEVELOPMENT

The World Commission on Environment and Development (WCED) formulated a report in 1987, known as the Burtland Report named after its chair G.H. Burtland. This report defined Sustainable development as "Sustainable Development is the development that meets the needs of present without comprising the ability of future generations to meet their needs". It was primarily based on two key concepts:

"One, the concept of needs particularly for worlds poor's and poor states should be prioritized above all and second, the harm advancing technology and social organization are causing to the environment to meet its present and future requirements" (Burtland 1987).

Construction industry plays a significant role in use of earth resources. Thus it plays a very important role in sustainable development of any economy. Efficient use of resources has become eminent now; Planner, Designers and Constructors should have a clear understanding of the impact of their action on the environment. Buildings constructed today should have a useful life of forty years before it goes under major renovation or uplift; so it uses lots of resources not just during construction but throughout its operation and maintenance. With growing population and the ever growing need of building networks it seems impossible to cut down the use of energy and resources, however alternate form of energy and smart technologies can be adopted to meet these needs.

2.3 DEFINING GREEN BUILDINGS

Green building is the practice of maximizing the efficiency with which buildings and their sites use resources, energy, water, and materials while minimizing building impacts on human health and the environment, throughout the complete building life cycle from planning, design, and construction to operation, renovation, and reuse. (USEPA 2008). Another definition according to American Society of Testing Material (ASTM) is: Green building provides specified building performance while minimizing disturbance to and improving function of local, regional, and global eco-system both after its construction and specified service life (ASTM 2006). The definition focuses on not just the design and construction of facility on principles of sustainable construction but also considers the impact of the building throughout building's life cycle on the environment. The impact of buildings and construction is evident from the fact that developed nation like United States of America has high resource consumption and waste production by commercial construction activities; some facts are:

- 72% of electricity consumption (USEIA 2008)
- 39% of energy use (USEIA 2008)
- 38% of all carbon dioxide produced (USEIA 2008)
- 40% of raw material used (Lenssen and Roodman 1995)
- 30% of waste produced "136 million tons annually" (USEPA 2007)
- 14% of potable water consumption (USGS 2000)

Green buildings are the facilities designed and constructed with the idea of minimum environmental impacts, these are supposed to be environmental friendly buildings. In principle green buildings reduce the negative impact of building structures on natural environment and the human health through efficient site layout, energy use, material selection, waste management, indoor air quality, construction operations and maintaining occupant health. Thus the word green is also used as a synonym for sustainable construction. Sustainable buildings are a high performance buildings and significantly better than the traditional buildings. Concurrently in order to achieve these high performance Sustainable facilities the planning, design, construction, procurement and contract processes all have to be quite different from the traditional ones. A more interconnected approach is required by all disciplines at all stage of the building process. The process of thinking Green comes with an integrated thinking process from all team members.

2.3.1 TRADITIONAL PROCESS

In traditional building process the specialists usually works in an isolation focusing on their work of expertise only, they work together only when necessarily required. It is generally a discipline to discipline step wise movement without much interaction with each other. Traditional building process follows the conventional steps as shown in figure 2.1

Figure 2.1 Old way of building (Adapted from: GBES 2009)

2.3.2 INTEGRATED PROJECT DELIVERY

Integrated project Delivery (IPD) is an approach that brings in all the stakeholders to a collective and an integrated process so everyone brings an insight through wisdom and experience to deliver an efficient product with reduced waste and maximized performance in design, construction and operations (AIA 2007). Integrated project delivery is an example pure of team work it's a complete collaboration between all stakeholders of a project from inception to completion. Stakeholders may be the client, building owner any tenant, contractor or end user, involvement of all makes the project efficient and sustainable. IPD results in a greater efficiency, in most of the cases integrated teams have been able to achieve more savings than a conventional project delivery process. Collaborative team effort identifies the goals of project early in planning phase. Project phase of IPD are shown in figure 2.2

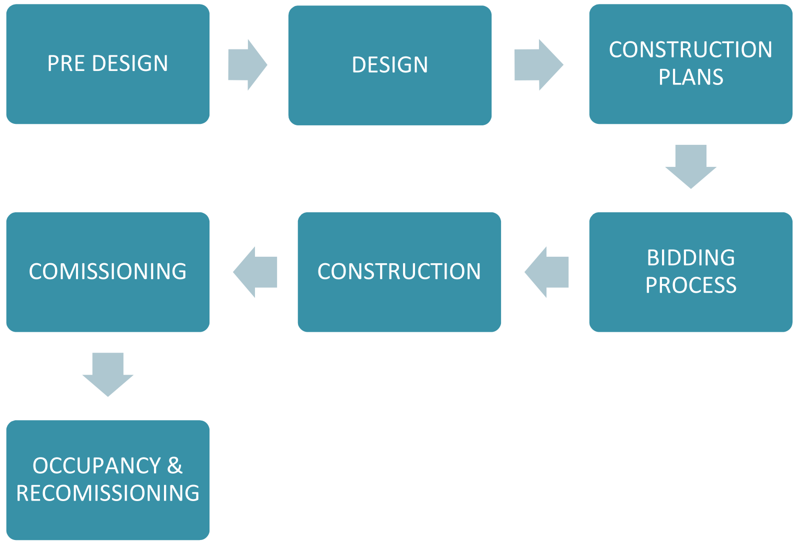

Figure 2.2 IPD Process (Adapted from: GBES 2009)

Table 2.1: IPD compared to Traditional Project Delivery Process

Processes/ Steps	**Traditional Project Delivery**	**Integrated Project Delivery**
Teams	Hierarchical, working independently as needed.	Collaborative, integrated, assembled as early as possible.
Process/ Schedule	Linear, working is silos	Concurrent; shared information
Risk	Individual Risk	Shared equally
Compensation	Individually based	Based on team success
Communication	Paper based	Digital and virtual
Material/ Strategies	Least expensive to meet code	Life cycle analysis and cost
Project phases	Design-occupancy	Pre-design phase; green building goals are reviewed at every phase

Integrated project delivery process is the process to achieve green development. It initiates with a pre-design phase which starts with a project vision, programming, budgeting and defining green building goals thus formulating the groundwork of entire project. Second step is of selecting the green building team; every member of the team should be committed to green project objectives to achieve a state of the art energy efficient building. Selection of project Green team is followed by the technical Design process and preliminary project budgeting. The Green project budget is a step ahead of the traditional budgeting as it includes life cycle cost analysis. The green project needs the team of experts to evaluate the cost for its entire life. Remaining steps are of bidding, construction and handing over; however the main difference is that the entire project team is involved throughout the project at each of these steps. Some of typical differences between Traditional and Integrated Project Delivery System are shown in the table 2.1

2.3.3 TRIPLE BOTTOM LINE

One of the key indicators of true Sustainability is Triple Bottom Line. Traditional bottom line of any business or project is the financial bottom line. No one wants to run a business as a non-profit entity; everywhere financial bottom line is the important decision making line. It primarily concerns the profit or loss in any project and on basis of that projects are evaluated. However in Triple bottom line Sustainability is the prime concern which is based on three main aspects:

- Economics
- Environmental
- Social Responsibility

Triple Bottom line is based on these three aspects in addition to the traditional bottom line. It defines new dimension of considering economic, environmental and social context in addition to financial aspect (figure 2.3). Green projects should not be considered for its financial liability only but its response to environment and social responsibility. Green projects framework takes into account the ecological balance, economic growth and social equity.

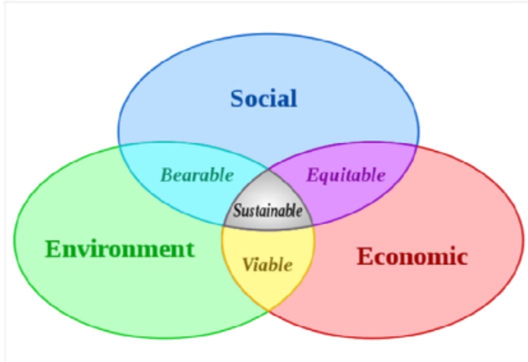

Figure 2.3 Triple bottom line (Adopted From: Burtland Report 1987)

2.4 GREEN CONSTRUCTION

Green construction is planning and managing construction projects in accordance with the contract documents in order to minimize the impact of construction on the environment (Glavinich 2008). This statement explains the proactive approach of the contractor in regard to the environment. Entire team of construction project should work in accordance with the contract requirement to achieve environment friendly structure. The responsibility of Green construction just not lies in the hands of construction contractor but the entire team involved in contract development and bidding process. Thus it is very much an integrated approach with inputs and follow-up from all stakeholders. The project team to achieve Green should look for ways to minimize the impact of construction process on environment by 1) improving the efficiency of construction processes 2) minimizing the amount of construction waste 3) conserving energy, water and other resources during construction (Glavinich 2008).

2.4.1 PROACTIVE OR REACTIVE

In past approach towards green construction has mostly been reactive. The contractors tend to follow what has been contained in the contract documents. Contractor builds just what is contained in the drawings and specification of the project documents. However with the passing time stakeholders and environmental regulatory bodies are becoming concerned about the building industry’s impact on the environment. Construction contractors are generally facing problems and challenges in meeting the environmental considerations of reducing waste and environmental impact during construction. Mostly these types of considerations are motivated from environmental laws and most importantly the stakeholder's interest and demands (Qi et al. 2010). Therefore it is becoming difficult for the contractors to compete in the current market with the passive attitude towards environment. One has to be very concerned about the impact of their actions on the environment. Clients of today also prefers services of proactive green contractor whose past projects reflects the concern for environment. So the construction industry has to respond to the ever growing environmental concerns proactively in order to achieve sustainable development. Young employees and engineers are also concerned to work for environmental conscious firms as they want to be part of the solution and not the problem, similarly the public is also becoming increasingly concerned about the environment and there is increasing focus on all industries including construction that could result in increased governmental regulation and compliance costs for those industries that do not take a proactive approach to the environment (Glavinich 2008).

2.4.2 GREEN IS LEAN

Minimizing the construction waste and recycling is the key sustainability indicator. Lean construction explains the concepts of reducing waste in production and the flow processes. Management up till now has been more focused on the conversion process and not on the flow process of developing the product which leads to unnecessarily prolonged activities and an inefficient output (Alarcon 1997). The term of lean is primarily related to industrial production and concept of reusing and minimizing the waste by efficient flow process. However it makes an equal sense for construction activities as green development demands for efficient use of resources by minimizing the waste. Lean construction focuses on waste reduction and disposal by an efficient method in order to minimize the environmental impact, including construction waste diversion, recycling and reuse to enhance environmental performance (Glavinich 2008). On a demolition site, deconstruction of any building may reveal to the builder lots of recyclable and reusable material, for example a demolish buildings slab may provide steel (recyclable material) and concrete which can be used as a crush refill material.

2.5 GREEN BUILDING EVALUATION SYSTEM

The significant impacts of construction activities on environment have triggered a serious alarm and the governments worldwide have introduced various policies and regulations for controlling them. These laws have been formulated in almost every part of the world; however enforcement has yet to be perused for better results. For instance in China the government has issued a series of laws including environmental protection law, the cleaner production promotion law, the pollution prevention law and reproducible energy law (Qi.G et al. 2010). In terms of energy savings and discharge decrease the government has set various objectives in a plan named "Eleventh Five year plan", by stipulating three obligatory indexes: reduction of energy consumption per unit of GDP by 20%, reduction of water consumption per unit of GDP by 30%, reduction of total major pollutant emissions by 20% (NBSC 2007).

Alongside the sustainability and environment specific laws, green building certification and evaluation system has been introduced to the world. The idea of Green building certifications is to stimulate the green building competition, recognize and reward the best sustainable building practices. The certification process has helped increase the awareness in general public, potential clients, designers and contractors. Energy certification schemes for buildings emerged in the early 1990s as an essential method for improving energy efficiency, minimizing energy consumption and enabling greater transparency with regards to the use of energy in buildings (Lombard et al. 2009). Sustainable building rating systems are defined as tools that examine the performance or expected performance of a whole building and translate the examination into an overall assessment that allows for comparison against other buildings (Fowler K and Rauch E 2006). Some of the most significant and widely used sustainable building evaluation and rating systems are summarized below.

2.5.1 BUILDING RESEARCH ESTABLISHMENT'S ENVIRONMENTAL ASSESSMENT METHOD (BREEAM)

BREEAM rating system is most widely used in United Kingdom however it is not so popular in United States. It was established in 1990 for evaluating building performance in context of sustainability. The assessed building is awarded with points against each criterion with added total at the end revealing the overall building standing. The overall building is then awarded a PASS, Good, Very Good or Excellent rating based on the score. In accordance to US department of Energy report on sustainable building rating system by (Fowler and Rauch 2006); BREEAM major categories for design and procurement include:

- Management (commissioning, monitoring, waste recycling, pollution minimization, materials minimization).
- Health & Wellbeing (adequate ventilation, humidification, lighting, thermal comfort).
- Energy (sub-metering, efficiency).
- Transport (emissions, alternate transport facilities).
- Water (consumption reduction, metering, leak detection).
- Materials (asbestos mitigation, recycling facilities, reuse of structures, facade or materials, use of crushed aggregate and sustainable timber).
- Land Use (previously used land, use of remediate contaminated land).
- Ecology (land with low ecological value or minimal change in value, maintaining major ecological systems on the land, minimization of biodiversity impacts).
- Pollution (leak detection systems, on-site treatment, local or renewable energy sources, light pollution).

2.5.2 GREEN GLOBE US

Green Globe US was adapted from Green Globe Canada rating system in 2004. Green Globe US is an on line tool developed for use by Architects and builders for primarily assessing environmental impact of commercial buildings. It is developed by combination of BREEAM and Green Leaf. In Green Globe rating system assessment is done in two stages; first after completion of Concept design and final after construction documentation stage. In accordance to US department of Energy report on sustainable building rating system by (Fowler K and Rauch E 2006); Green Globe US major categories for design and procurement include:

- Project Management (integrated design, environmental purchasing,
- Commissioning, emergency response plan)
- Site (site development area, reduce ecological impacts, enhancement of
- Water shed features, site ecology improvement)
- Energy (energy consumption, energy demand minimization, “right sized” energy-efficient systems, renewable sources of energy, energy-efficient transportation)
- Water (flow and flush fixtures, water-conserving features, reduce off-site treatment of water)
- Indoor Environment (effective ventilation systems, source control of indoor pollutants, lighting design and integration of lighting systems, thermal comfort, acoustic comfort)
- Resource, Building Materials and Solid Waste (materials with low environmental impact, minimized consumption and depletion of material resources, re-use of existing structures; building durability, adaptability and disassembly; and reduction, re-use and recycling of waste).

2.5.3 LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED)

Sustainable construction techniques includes implementing a sustainable design, meeting or exceeding sustainable design specifications, developing strategies to minimize and reuse construction waste and spoils, optimizing asset efficiency, and pursuing the highest level of LEED certification possible. LEED was developed in United States of America in 1998. There are four levels of LEED certifications:

- Certified 40-49 points
- Silver 50-59 points
- Gold 60-79 points
- Platinum 80+ points

The sustainability of a LEED project is evaluated on a 100 point scale with an additional 10 bonus points. The LEED reference guide presents detailed information on how to achieve the credits within the following major categories:

1. Sustainable Sites (construction related pollution prevention, site development impacts, transportation alternatives, storm water management, heat island effect and light pollution)
2. Water Efficiency (landscaping water use reduction, indoor water use reduction, and wastewater strategies)
3. Energy and Atmosphere (commissioning, whole building energy performance optimization, refrigerant management, renewable energy use, and measurement and verification)
4. Materials and Resources (recycling collection locations, building reuse, construction waste management, and the purchase of regionally manufactured materials, materials with recycled content, rapidly renewable materials, salvaged materials, and sustainable forested wood products)
5. Indoor Environmental Quality (environmental tobacco smoke control, outdoor air delivery monitoring, increased ventilation, construction indoor air quality, use low emitting materials, source control, and controllability of thermal and lighting systems)
6. Innovation and Design Process (LEED® accredited professional, and innovative strategies for sustainable design)

2.6 GREEN BUILDING CHARACTERISTICS

In order to develop in a sustainable way, it is an urgent task to disseminate the concept of sustainability and put it into practice for urban construction (Zhu and Lin 2004). There is an immense need to bring awareness in the construction sector to adopt the ways of Green construction. Research shows that sustainable building practices can considerably reduce the built environment’s role in energy consumption, according to a survey of 99 green buildings in the United States green buildings use 30% less energy than the conventional buildings (The rise of Green Buildings 2004). Buildings to exhibit Green characteristics need to show compliance with the best practices and green codes. The facilities should 1) minimize the negative impact on the environment; 2) Introduce renewable source of Energy; 3) Prefer use of environment friendly material; 4) Maintain indoor quality; 5) safe fresh water; 6) Apply life cycle approach. Table 2.2 below shows the characteristics of a green building.

Table 2.2 LEED Category & Ratings

CATEGORY	**POINTS**
Sustainable sites	26
Water Efficiency	10
Energy & Atmosphere	35
Material & Resources	14
Indoor Environmental Quality	15
TOTAL	**100**
Bonus Points	**-**
Innovation & Design	6
Regional Credit	4
TOTAL	**10**

2.6.1 SUSTAINABLE SITES

Creating sustainable buildings starts with proper site selection. The location of a building affects a wide range of environmental factors, including energy use, land use and preservation, erosion and storm water control and access to public transport (GBES 2009); Sustainable site design uses the whole building design approach which is primarily focused to:

- Protect undeveloped Land
- Reuse/ restore previously developed sites
- Reduce automobile use or promote alternative transportation

- Efficient storm and rainwater management
- Reduce heat island effect
- Reduce light pollution or minimize light trespass from the building site

Selection and development of site is the most important factor for sustainable development in a building project. Proper site selection can help save energy, landscape and vegetation. Site should ideally be located in proximity to public transport in order to reduce the use of personal automobiles. While selecting the land for development care should be taken not to; use prime farm land, public parkland, areas below flood plain, land close to lakes, streams or other water bodies. The selected site should address the key factors of sustainability for an environment friendly development. It is always preferred to; reuse contaminated land "Brownfield" by cleaning it up and bringing back to usable condition, develop already developed land, develop in dense area and provide community connectivity.

The second most important step after selection of site is its development in lieu of sustainability. The building team should try to make the building footprint minimum and maximize the open land. The impacts of site development on environment like loss of top soil, destruction of ecosystem, loss of mature trees and plants should be minimized. Restoration of natural and manmade areas in your site is a sign of efficient development thus efforts should be made to restore the land as much as possible.

2.6.2 ENERGY AND ATMOSPHERE

In all of the LEED rating systems, the Energy and Atmosphere category contains the most credits available. The reason is importance of energy conservation. Increased energy use and burning of fossil fuels are linked to global warming and pollution. This category of sustainability specifically looks at the energy use in building: use less energy and support use of more environmental friendly energy sources (GBES 2009).

The building team should first set a energy target and work in accordance to achieve that allowable energy use throughout its life. According to (GBES 2009) United States of America, buildings account for:

- 36% of total energy use
- 65% of electricity consumption
- 30% of greenhouse gas emission

The figures above emphasize on cutting down the use of energy and electricity. This can be done by smart engineering design, technology and human behaviour. The building orientation with south facing envelope for more heat gain; the building location may be placed close to and under trees in hot areas. Ample cross ventilation and natural light to cut down the use of electrical, mechanical appliances is also important. Selecting energy efficient appliances and equipment is as important as proper location and orientation. Finally the use of Renewable energy is also an efficient way to address the environmental concerns. Using solar panels as an addition or alternate to grid electric supply, geothermal heating and cooling, solar water heaters, wind turbines are all examples of alternate energy or renewable energy.

2.6.3 WATER EFFICIENCY

If our present water usage pattern continues, two out of every three people will live in water-stressed conditions by the year 2025 (UNEP 2000). Scarcity of fresh water is becoming a serious issue as many parts of the world are faced with water shortage. Water efficiency helps protect the water depletion and ensures supply of renewable fresh water. By reusing the water one can save upon the municipality water supply. The main intent of water efficiency is reuse of grey water and storm water in order to minimize the requirement of potable water. Three main sources of non potable water which can be used by little or more treatment for non potable purposes are:

- Storm water (rains and flood)
- Grey water (Bathtubs, showers, washing machines)

- Black water (toilet/ Flush)

Storm water or reclaimed rain water requires minimum treatment for non potable reuse. Grey water on other hand requires a little more treatment as it contains various chemicals which need to be disintegrated from the rest of water. Black water however requires a lot more treatment to be fit for non potable purposes. The importance of water management is evident from the fact that every global green building rating system gives high weight age to water reuse. However there can be different indoor and outdoor strategies address water efficiency.

2.6.4 INDOOR ENVIRONMENTAL QUALITY

Indoor environmental quality refers to the quality of air and environment inside buildings, based on the pollutant concentrations and conditions that can affect the health, comfort and performance of the occupants (GBES 2009). Indoor air can be two to five times more polluted than outdoor air (USEPA 2008). Indoor environmental quality just not accounts for good design and construction but healthy occupants. Occupants can only be happy when they feel healthy and that comes with environment and user friendly design. An occupant can be a building owner; who lives there, an employee; who spends eight to ten hours there and a student who spends four to five hours on campus. The building should offer ease of maintenance, housekeeping and usage. Control on natural light, ventilation, temperature and good views outside the building gives the user a comfortable response. The variable that affect the indoor environment include:

- Air Quality
- Lighting
- Temperature
- Acoustics
- Humidity

In this world of growing competition the challenge is not to build aesthetically pleasing or structurally sound buildings but highly productive and healthy indoor environments.

2.7 WATER RESOURCE MANAGEMENT

Each day 340 billion gallons of fresh water is withdrawn from rivers, streams, and reservoirs. Sixty five percent of the water consumed is discharged back into the water supplies after use (GBES 2009). This is emphasised by the fact that city of Rawalpindi (Twin city of Federal Capital) alone is extracting 120 million gallons of water per day with the help of 240 tube wells, thus depleting the groundwater table by ten feet per year (Haq et al. 2007). Impression is usually held for hotter regions to be prone to water shortage but studies have revealed that country like United Kingdom also has water supply problems. Pakistan on the other hand is one of the most water stressed countries of the world (Briscoe and Qamar 2006) as shown in figure 2.4

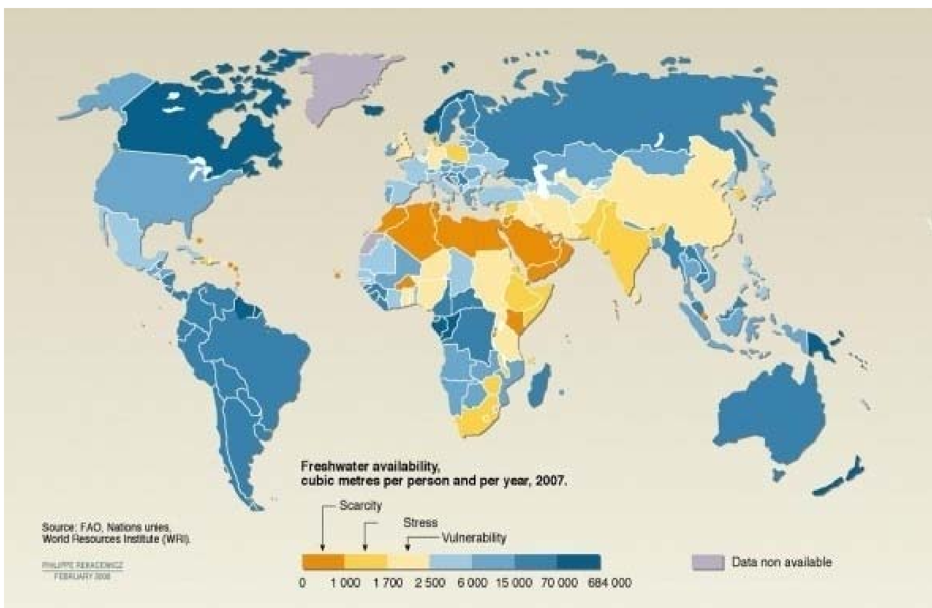

Figure 2.4 Availability of Fresh Water & Groundwater Recharge (Adopted From: FAO 2009)

One of the most alarming fact is the speed with which the water availability per capita is declining, if the current pattern of water usage continues Pakistan is most likely to fall under water scarcity per capita (Briscoe and Qamar 2006).

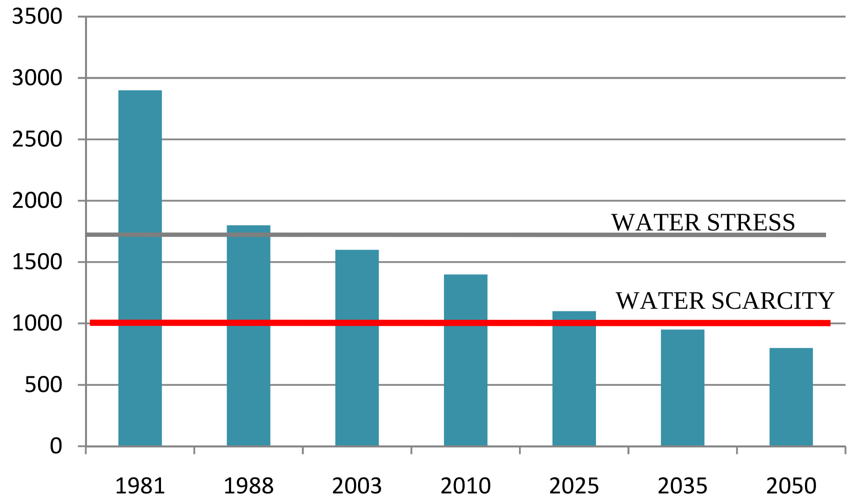

Figure 2.5 Declining per capita Availability of water; cubic meter per capita per year, Pakistan. (Adapted From: Briscoe and Qamar 2006)

Figure 2.4 and figure 2.5 are a clear indicative of the approaching problem, if not solved would lead us to below water scarcity line by 2035. This problem is not just because of the declining water availability but mostly because of the water use pattern and construction industry plays a major role in it. So the problem is not pertinent to one or two states but it is a rising global issue which can be fought with better water resource management. Different strategies may be adopted to reduce water use and reuse water for non potable purpose.

2.7.1 OUTDOOR STRATEGIES

Water consumption varies with varying seasons; generally water consumption in summers is higher than that in winter. Consumption of water does not mean the human consumption but the outdoor natural environment also. Most common of the outdoors water consumers is the landscaping, turf maintenance and carwash. Outdoor strategy also includes managing and storing of storm and grey water for non potable use. Different strategies should be adopted for water conservation and reuse.

2.7.1.1 Landscaping

A typical suburban lawn consumes an estimated 10000 gallons of water above and beyond rainwater each year (Vickers 2001). Most important is the first step; landscape design. The design should be carried out with objective of proper landscape design. The design should be done with intention to limit potable water use, decrease energy requirement for lawn mowing, requires less maintenance. The second most important aspect is selection of plants. There are three basic types of plants

1. *Native plants*- are those that grow naturally in an area and thus require less water, fertilizer and pest control to grow and survive.

2. *Adaptive plants*- can adjust well in a new environment. Adaptive plants also require less water and are more suited to region’s weather and soil conditions.

3. *Invasive plants*- grow aggressively by displacing other plants. These should be avoided. It is always advisable to do proper soil investigation and study of local plants which can survive naturally without much water requirement. Efficient ways and means to water the plants should also be considered for better water conservation.

4. *Drip Irrigation- is* one of the growing watering phenomena; in which water is delivered either directly to the roots or surface of plants by slow water dripping. Drip irrigation has an irrigation efficiency of 90% over conventional which results in 65% efficiency, however it is a bit expensive than conventional system (GBES 2009).

2.7.1.2 Storm and Grey water Reuse

Storm and grey water are non-potable and considered to be excellent alternatives. Storm water or reclaimed rainwater can be used as non potable water most prominently for; watering the garden, car washing, flushing the toilets. In addition it can be used during construction to minimize the use of fresh water. As, global fresh water resources are increasingly polluted and depleted, threatening sustainable development and human and eco system health and it is believed that freshwater would be the first natural resource to run short (Furumai 2008). Thus it has become inevitable in some parts of the world to store and reuse rainwater; however others can be proactive by adapting the means and learning from their experience and research to ensure sustainability. The achievement of sustainability is required ensuring a long term supply of water with adequate quality for all designated purposes minimizing adverse economic, social and ecological impacts (Furumai 2008). Storing and reusing of rainwater is very useful as it facilitates an emergency need also it is an educative process for community to understand the importance of sustainable water use. The process of storing storm water for reuse also helps to control the runoff running around in the streets and the neighbouring property.

Gray water is untreated waste water that did not come in contact with toilet waste. Gray water can be reused for non potable purposes after little treatment. Gray water is termed for the water that is coming mainly from Bathtubs, Showers, Bathroom sinks and Washing machines. This water contains chemical like washing soda, detergents, etc which need to be removed from the water to make it reusable. This water is great for landscaping and reusing for toilet flushing. The process is useful in high-rise residential projects as they will have amount of gray water available from the residents; showers and washing machines (GBES 2009). Figure 2.6 below gives a complete water reclamation cycle where rain water and water coming out of the building as waste is reused.

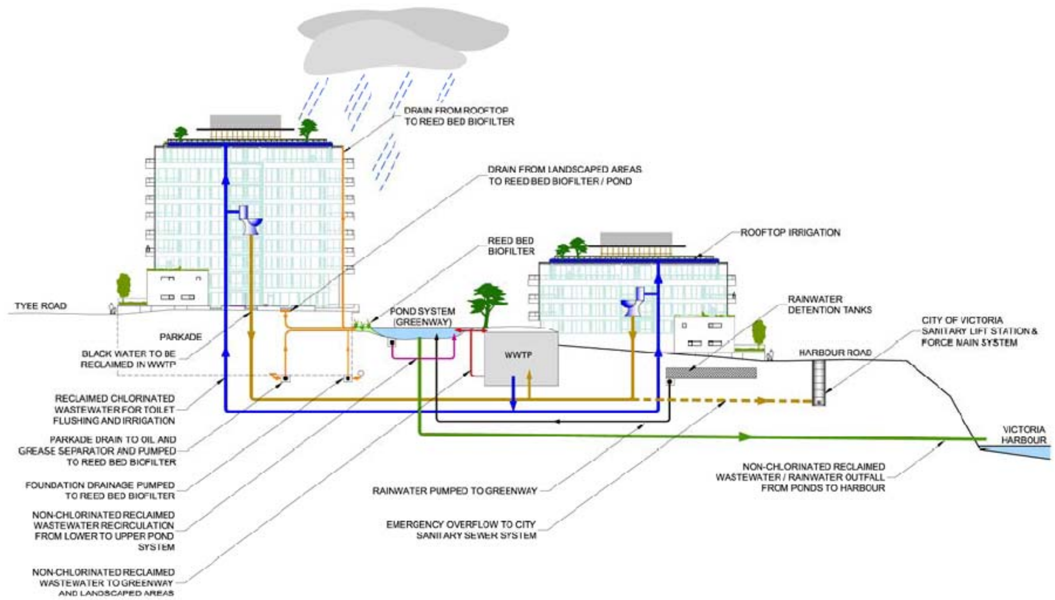

Figure 2.6 Reclaimed water use process (Adopted From: Dockside Green 2009)

2.7.1.3 Infiltration Planters

Infiltration planters are the term used for filtration tanks covered with vegetation on top. Various campuses and towns where ground water is depleting or contaminating the natural water streams, lakes and aquifer use these planters to address the issue. As shown in figure 2.7 and figure 2.8 infiltration planters may be built along the roads aside walkways, where water is collected through street gutters and goes down to the tank through layer of pervious materials. It may consist of top soil having silt- clay with layer of sand and gravel beneath.

Figure 2.7 Infiltration Planter (Adopted From: Virginia Storm water specs 2011)

Figure 2.8 Storm Curb Planter (Adopted From: Virginia Storm water specs 2011)

2.7.1.4 Bio Retention ponds

These are shallow areas which take up where the surface runoff water can be directed, typically they appear like landscaped area with native grass or turf on top and filtration bed of various impervious layers beneath. The Bio-retention are eco friendly solution to areas where the run offs are contained with pollutants. It not only collects the water through perforated pipes at the bottom but also recharge the aquifer through infiltration. A typical example of these can be seen in figure 2.9 and figure 2.10 below.

Figure 2.9 Bio retention pond (Adopted From: Virginia Storm water specs 2011)

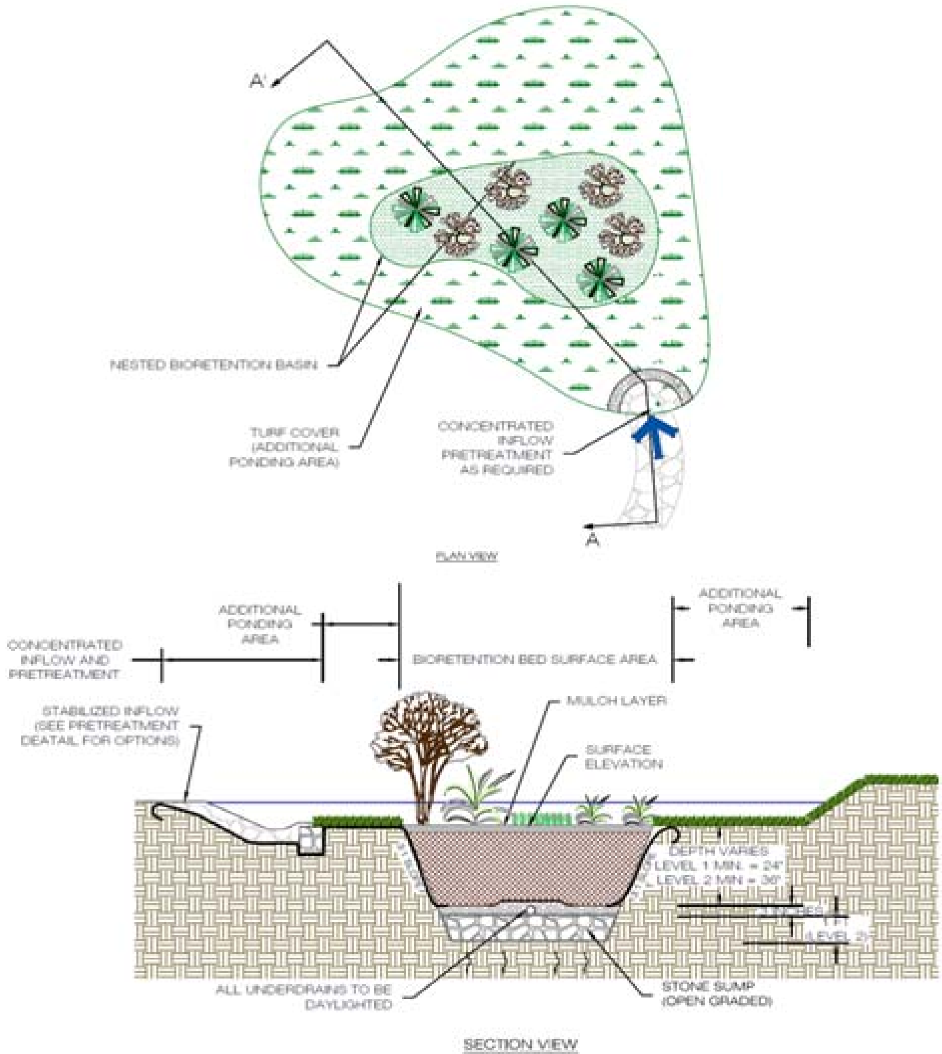

Figure 2.10 Typical section of bio retention pond (Adopted From: Virginia Storm water specs 2011)

2.7.2 INDOOR STRATEGIES

Water is one of the most consumed natural resource in domestic, commercial, public or any indoor facilities. Water conservation strategies can be defined to reduce the use of fresh water. In households water is mostly consumed in bathing, flushing, dishwashing & cloth washing. About half the water put into supply is produced in order to meet household demand and the quantity of water used by household in UK increased by 55% in the last 25 years (DEFRA 2008). Some of this increase is attribute to the population growth rest is mainly due to the prevalence of domestic technologies like washing machines and power showers (Adeyeye 2011). Two key indicators of sustainable water use are positive human behaviour and use of appropriate technology. Technology has been continuously advancing in an effort to minimize water usage which however depends on the occupant's response. There is a need to bring awareness amongst the people of water reuse advantages. Water reuse in housing can actually be achieved with little additional cost as it does not necessarily requires very high end technology to achieve the goals of sustainable water use.

2.7.2.1 High Efficiency Toilets

Studies have revealed that use of toilet is one of the major water consuming activities. United States toilets alone account for 25% of daily water use (GBES 2009). Similarly, in United Kingdom 30% of water supplied to the domestic sector is used for flushing and transportation of foul waste (Feweks 1999). (Burkhard et al. 2000) calculated that of all water fit for human consumption supplied to homes each year, 33% is used to flush toilets. 1.6 million gallons of water is wasted in the United States every year because of inefficient toilets (GBES 2009). Therefore replacing the old and less efficient toilets with high efficiency toilets has become inevitable. Most countries around the world have passed legislation to replace old and less efficient toilet fixtures with new efficient ones.

1. *Dual flush- water* closet has two levers; one provides half flush and the other full flush depending upon the type of waste produced.

2. *Waterless Urinals*- are kind of the products that can save a lot of money and time. Replacing a standard urinal with waterless urinal would save an average of 40000 gallons per year (GBES 2009).

2.7.2.2 Low Flow Water Fixtures

Low flow fixtures contribute significantly to sustainable water use by reducing the need of water. Swapping your 2.75 gallon/ minute shower with a

1.75 water conserving showerhead can save more than 7,700 gallons of water per year; based on 7 minutes shower per person family of four (GBES 2009). A faucet with 1.5 gpm flow aerator can save 30% more water over a faucet with a 2.2 gpm standard aerator (GBES 2009). Leaky faucets also contributed to the water waste, as according to a leading manufacturer Kohler a leaky faucet leaking at a rate of 60 drips per minute, wastes over 2000 gallons of water annually.

2.7.2.3 Water Reduction strategies

Some of the other means of saving fresh water use is to replace process water by reclaimed rainwater or treated water. Process water means water used in:

- Mechanical systems for cooling and heating the buildings,
- System used for laboratories,
- Commercial cooking support; steamers & ice-machines

The prime example can be of cooling tower which uses significant quantity of potable water to support the HVAC systems. This water can be replaced by non potable water.

2.8 SUMMARY

The public is becoming more aware of the benefits of green construction as prominent political personalities, celebrities, documentaries, and media coverage highlight the built environment’s impact on greenhouse gas emission and natural resource consumption (Robichaud and Anantatmula 2010). There is a need to change the traditional methods of construction and designing process to achieve Sustainable development. However conventional construction and management procedures need to be changed to attain sustainable development. The chapter discusses the procedures to attain Sustainable development in building industry. Sustainability is a generic term and needs to be specified and understood by each discipline and profession. Sustainable construction starts from the program stage to the life cycle operations and maintenance of any facility. Green construction primarily needs an integrated team approach.

Sustainability is to be Green; minimizing the impact on environment, water resource management, material selection, sustainable site selection, use of renewable form of energy, maintaining indoor environmental quality. Global incentives are given to market leaders in sustainable development. Facilities are evaluated for their response to environment and appreciated by different certifications. One of the biggest threats to the globe is fresh water scarcity and changing weather patterns governed by global warming. Reuse of storm and rain water has become inevitable, ground water levels are falling day by day. Fresh water is extracted at a rate much more than the rate of recharge. Strategies are addressed in this chapter to tackle the challenging situation. Indoor and outdoor techniques are discussed in detail to reduce water use and reuse reclaimed rainwater and grey water to fulfil non potable water requirement by non potable means.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This particular chapter discusses the methodology adopted for the research. It discusses in detail the method by which data was collected and examined to extract the required results. The research process is based upon nine step model (figure 3.1). Research methods in Behavioural sciences, say that, although the basic logic of scientific methodology is the same in all fields, its specific techniques and approaches will vary, depending upon the subject matter.

The first and foremost important step is formulating a research problem. Research problem identification gives a direction of the research topic, influencing the follow up steps. This was then followed by a thorough literature review for identification of the past researches there processes and results as discussed in the previous chapter. The third task was to conceptualize a research design in order to develop association and causation for extracting the required result and identify what has already been done and what gaps are left. Identification of the objectives was the fourth and the most important step which helped in defining the research parameters. Research objectives kept us on the track to progress towards the required data analysis and results. Constructing Data collection and evaluation instrument was very much required to identify the way by which the data would be collected and evaluated for the required result. Autodesk's Autocad was the software used to collect the data, primarily for area calculation from the proposed master plan by National Engineering Services (NESPAK) who were the prime consultant for National University of Science & Technology's master planning. Satellite imagery was also used to identify the current development level as of April '2011. The data was however processed by use of rational method for calculating the storm run-off as suggested by (Steel and McGhee 1997). Recommendations are given finally by identifying ways and means to adopt the research findings.

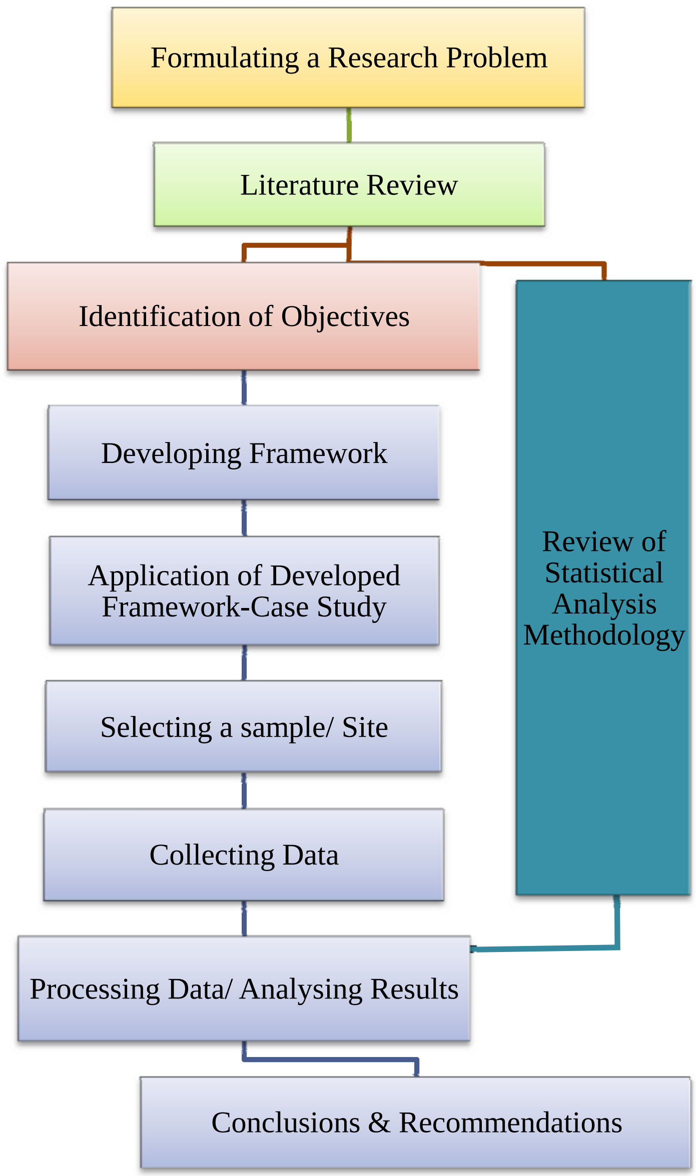

Figure 3.1 General Study Framework

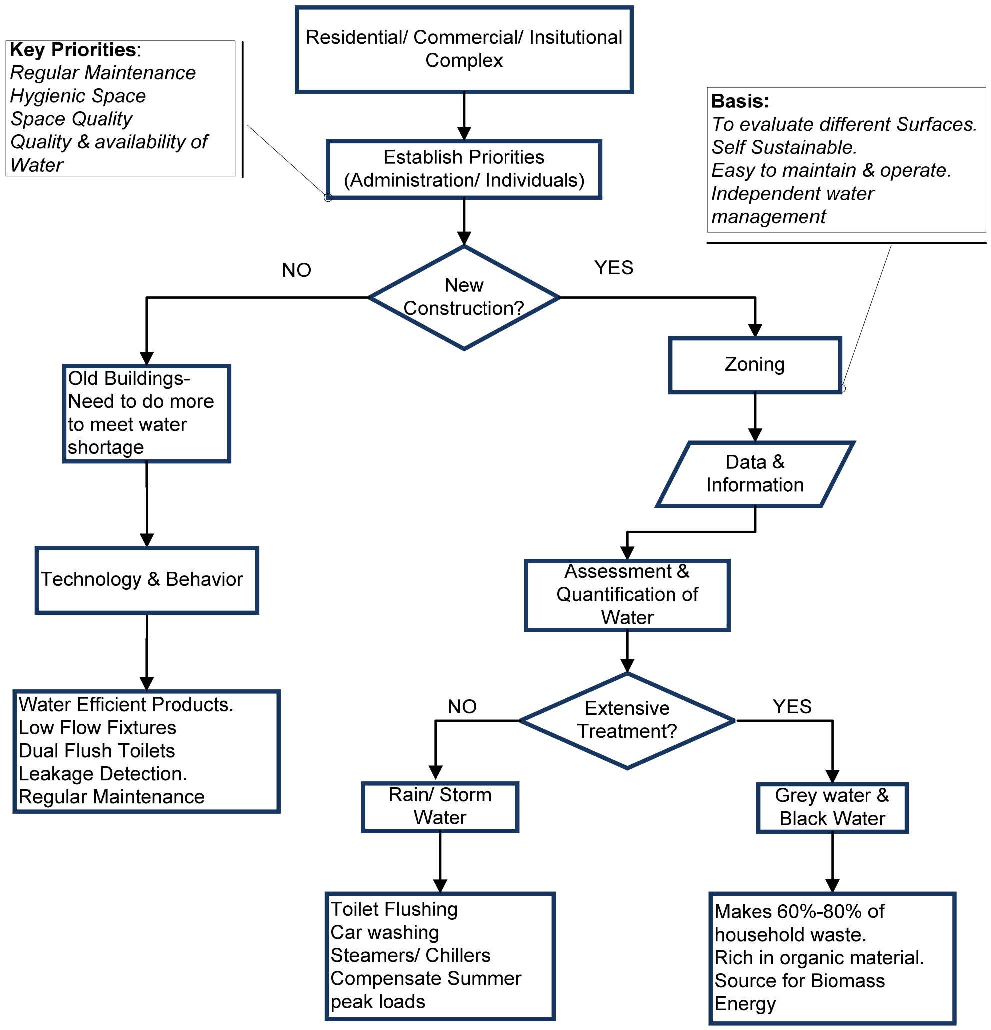

Figure 3.2 Framework for water reclamation

3.2 FRAMEWORK FOR WATER RECLAMATION

This particular section discusses a generic framework for water reclamation in large complex of buildings, master planning's and infrastructure development as shown in figure 3.2. The framework focuses on planning and process of collecting and analysing data for studies pertaining to sustainable water use and its efficiency in built environment. The developed framework addresses the issues of both new and old construction and identifies process related to both in order to achieve the desired objective of water conservation. Different strategies are suggested for both new and old construction respectively

3.2.1 ESTABLISHING PRIORITIES

The first and the foremost important thing for the researchers, developers, architects and constructors in establishing such framework are to set priorities and importance of work. Prioritizing the work would identify the goals and objectives which are of high importance. In master planning and building construction the key priority is to deliver an end product which is highly efficient in it s ambiance and performance. The facility should be easy to manage and should have a high social, economical and environmental response. It should be to provide end user the comfort and ease of use and maintenance. Some of the key priorities of an owner, facility manager or the end user are:

- Regular maintenance
- Indoor space quality
- Environment quality
- Availability of quality water

3.2.2 ZONING

Zoning is the process of dividing larger study area, particularly in case of master planning’s into smaller sections. In order to evaluate these large complex and networks of building with infrastructure stretching in acres of land is advisable to divide into smaller, more manageable groups. This could be done by defining the boundaries and setting limits to the areas being divided. This way the larger areas of land can have smaller zones, and each zone can then be evaluated for the amount of rain, storm, grey and black water being discharged into the drainage and sewer system. Zoning not only helps in making the data collection and assessment easier but also facilitates in controlling and running the facility thus making it more efficient and sustainable. Zones are generally based on invisible boundaries made by roads, pavements, streams, or terrains.

3.2.3 EXISTING FEATURES

Developing in urban or even in rural area one is highly likely to come across existing features which may include Buildings, Bridges, Canals, Roads, etc. Sustainable approach is to reuse and retrofit the existing facilities as per the identified objectives. In an already developed land there would be structures of different ages and functionality which need to be dealt accordingly. To make an existing facility efficient in its water consumption emphasise needs to be laid on occupant’s behaviour. The behaviour needs to be combined with technology by replacing some of the old conventional fitting with new and efficient ones. Some key factors to be considered while uplifting the new facilities are;

- Regular maintenance
- Leakage detections
- Low flow fixtures
- Dual flush toilets
- Rainwater for landscape

3.2.4 NEW CONSTRUCTION

New construction should be a thought through process of design and operations. One has the leverage of designing and constructing the facilities in compliance with sustainability pertaining to water reuse. While trying to build a water efficient product one has to consider the indoor as well as outdoor water reuse strategies. Various methods may be adopted to achieve a higher standard of efficiency. Unlike existing buildings new buildings can identify new processes and methods. New water collection and reuse system may be introduced for better results. Different type of sources for reclamation should be studied and strategies identified. New constructions would have more or less the same sources however a different collection, reuse and disposal system should be introduced. Sustainable water management demands complete water reuse and highly efficient disposal system with extra water to be used for aquifer recharge.

3.2.5 WATER QUANTIFICATION

Once different sourced of reclaimable water are marked, it is important to quantify the available amount to be reused. Data is collected for each zone depending upon the varying surfaces in each it. Each zone can be divided into various surfaces depending upon their type as each type of surfaces has varying water permeability level. Based on these type and permeability the coefficient is calculated; which gives us the amount of storm each surface would absorb or disseminate. The surface runoff can then be calculated by adding up all the runoff produced from each surface to reveal the total amount of water that may be treated and reused. The rain and storm water data is quantified using the rational formula method which is explained in later section of this chapter. This formula primarily depends upon the type of surfaces; their runoff co-efficient and the hydrological data; precipitation rate of the particular area. Similarly all the water coming out of the facilities as waste should be calculated for its impact and reuse ability.

The collected data was analysed by using the Rationale method for calculating the run-off water as per the limits laid down by Steel and McGhee (1997).

3.2.5.1 Rational Formula Method

The equation adopted to calculate the amount of storm and rainwater generated is called rational formula method. This formula was introduced in 1889 and most widely used in most of the engineering offices of the United States of America. The runoff water is calculated by using Rationale formula method (Steel and McGhee 1997).

$$\boldsymbol{Q = KCIA} \qquad \text{........................Eq. (1)}$$

Where;

Q is defined as the maximum rate of runoff in cubic meter per second,

K is the local adjustment factor for rational method,

C is the runoff coefficient,

I is the rainfall intensity, and

A is for the area

The runoff coefficient, C, represents the integrated effects of infiltration, evaporation, retention, flow routing and interception all which effect the time distribution and peak rate of runoff (Steel and McGhee 1997). Different surfaces have different C values due to the varying properties. Composite C is calculated on the basis of percentage of different type of surfaces by using the equation;

$$\mathbf{C} = \frac{(\mathbf{Ar\ x\ Cr}) + (\mathbf{Ap\ x\ Cp}) + (\mathbf{Ag\ x\ Cg})}{\mathbf{At}} \quad \ldots\ldots\ldots\ldots \text{Eq. (2)}$$

Where;

C is the composite runoff coefficient

Ar represents the roof area

Cr represents the roof runoff coefficient

Ap represents the pavement area

Cp represents the pavement runoff coefficient

Ag represents the green area

Cg represents the green runoff coefficient and

At represents the total area.

3.2.6 CHARACTERIZATION OF WATER

Out of the various sources available for water reclamation, it is important to mark the ones which we intend to use. However one of the most important aspects is to first characterize the extracted data. The type of data available would help us identify the level of treatment we require to achieve the desired results. The sources from old and new buildings are almost similar and their characteristic depends upon the type of facility they are for example an industrial waste water would be much more toxic than a residential waste. The typical water resources that may be reclaimed for use are:

- Rain water

- Strom water
- Grey water
- Black water

3.2.7 WATER EVALUATION AND UTILIZATION

Once the quality and quantity of data are extracted it is time to decide upon the level of reclamation required. This is further dependent upon the required use of the facility and current water use patterns of the occupants. The type of water would depict the type of treatment required. The more toxic the waste water is extensive the treatment is required. This leads us to the area where the reclaimed water can be used. In this case storm and rainwater can be reused for various purposes without extensive treatment for example rainwater with primary treatment can be used for;

- Toilet Flushing
- Car washing
- Landscaping
- Process water for chillers, boilers, etc.

3.3 PROPOSED WATER REUSE SYSTEM

Different techniques and process may be used to reuse reclaimed rain and storm water. The figure 3.3 gives a simple example of reclaimed storm and rain water cycle. This system can be incorporated into any existing building and much easily into new build outs. The water would be collected through drains along the paved areas from the roof and the runoffs from the undeveloped open land. The drains can than transfer the collected water into a sedimentation tank where it would let the suspended material settle down. This would then fall into the filtration tank consisting of layers of sand, aggregates and pebbles which would further purify the water which would eventually fall into the collection tank from where it can be pumped up to an overhead reclaimed water tank for supply.

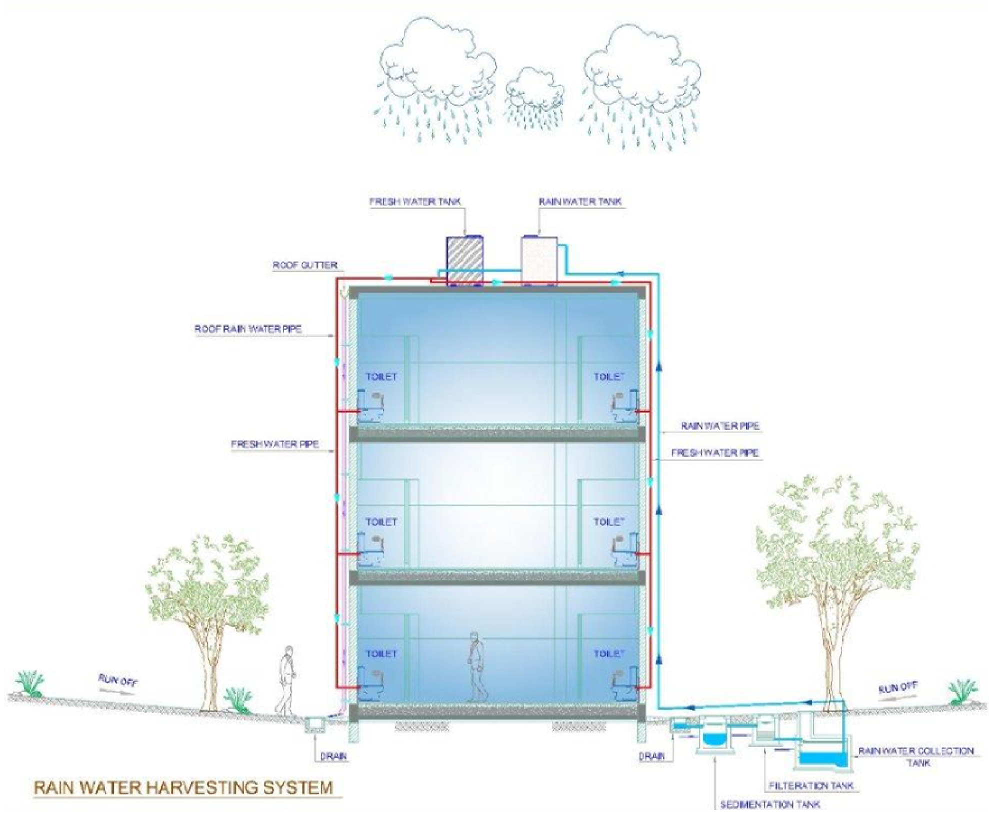

Figure 3.3 Proposed storm & rain water reuse mechanism

3.4 SUMMARY

The chapter focuses on and methodology that can be adopted for water reuse and conservation. A strategic framework for water reclamation is developed and explained comprehensively. The framework identifies the selection of the study site and pertaining features, how the data may be evaluated and what can be done for facilities or buildings that are already built and the ones that are yet to be constructed. The importance of zoning is explained when dealing with large complexes, infrastructures and what could be the basis for zoning a study into smaller units. Each zone or division becomes an independent entity for data collection and in this particular case for quantifying water. The qualitative and quantitative analysis of water from each zone would help identifying the form and type of uses possible. The use however would further make the basis for the type of treatment required. If an extensive treatment can be afforded all four identified forms of rain, storm, grey and black water can be used. However with primary treatment one can still make significant use by replacing fresh water use for non potable purposes like toilet flushing, landscaping, car washing etc.

CHAPTER 4

THE CASE STUDY

4.1 INTRODUCTION

A case study is an empirical inquiry that deals with technically distinctive situation in which there will be many variables. It relies on multiple sources of evidence and benefits from prior development of theoretical propositions to guide data collection and analysis (Yin 1994). Case study as research design comprises of all aspects of method analysis, strategy and results. Different strategies may be adopted to address the how and why of a research problem, which requires an in depth investigation to achieve desired results. Constructing the validity of the case study is foremost important thing in order to get convincing results. The following chapter explains the importance of a case study in collecting the evidence and emphasising a research problem by extracting actual results. A number of steps are involved in a case study which should be explained in a systematic pattern. The formulated steps require further elaboration to the adapted system and its impact. For sustainable water reuse study; a complex of building network in a dense and mildly developed area helped achieve varied results based on the type of characteristic. The larger and complex areas can be divided into smaller more manageable groups in this case *zones*. The data for each zone can then be calculated and results compared.

4.2 SITE SELECTION

Selection of appropriate site was a challenging task and it was based on certain criteria. The site primarily had to be a representation of an urban area with built environment of diverse nature. Secondly the scale and size of the selected area should be close to a very small city or a larger housing scheme with similar development patterns having at least basic amenities. Thirdly, the project should ideally be under development in order to compare the future development plans with the current development by effectively adopting the research findings.

For the purpose, National University of Science & Technology's (NUST) new campus at H-12 sector was selected. Keeping in view the limited time, resources and the above mentioned criteria the NUST, H-12 campus was selected. The National University of Science & Technology's new campus is being built on an entire sector of H-12, covering an area of approximately 702 acres. The selected site of NUST is still under development and would take few more years for complete development. The development pattern is however on need base, thus the infrastructure would increase as the time and need progresses. This means an increase in impervious surfaces and thus an increased water run-off. Currently NUST water supply demands are based on Tube wells and Municipality.

4.3 ZONING

In order to evaluate the potential water demand and generation through rain, storm and grey water, the entire site of National University of Science & Technology is divided six zones based on roads as the boundary of each zone. Each zone has its own salient features with varying functions of the built structures and the environment. Each zone is named after the type of function it serves and what majorly constitutes it to be a part of the whole site. The zones are further categorized into Building, Pavement and Green areas based upon their run-off coefficient. Based upon these categorizes each zone is evaluated for its amount of run-off water generated and the ability to re-use this water for non potable requirements.

Figure 4.1 Zone 1- I.T & Science & Technology

Zone 1 lies in the heart of the NUST campus and is surrounded by Indus loop (the circular road) as shown in figure 4.1. The science and technology hub mostly has institutional buildings called schools and on the either side are boys & girls hostels with central cafeteria’s and the administration building. Buildings with regular rectangular roof plans are the ones to be constructed and the rest with a more zig-zag patterns are already constructed ones.

Figure 4.2 Zone 2- Civil Engineering & Technology Park

Zone 2 is named after the School of Civil and Environmental Engineering as it has ones of its main institute building National Institute of Transportation and NUST Institute of Civil Engineering side by side. Along the schools are couple of boy’s hostels and a centre for innovation buildings. This zone has yet to be completely developed with current development patterns shown in figure 4.2

Figure 4.3 Zone 3- Lake & Sports Complex

The above figure 4.3 highlights the NUST area for sports and recreation. The zone however has Hostels for boys, central lake, sports stadiums and residences for supporting staff at the south east edge of the complex. The area would also have supporting buildings for the sports facilities to be built in the near future. Currently the zone only houses the Hostel buildings and the supporting staff residences buildings.

Figure 4.4 Zone 4- Residential Colony

Zone 4 is specifically dedicated to the hosing for the Faculty mostly consisting of Apartment buildings and independent houses (figure 4.4). This zone like others is also under development and not yet completed however some of the buildings are completed and occupied by the staff already.

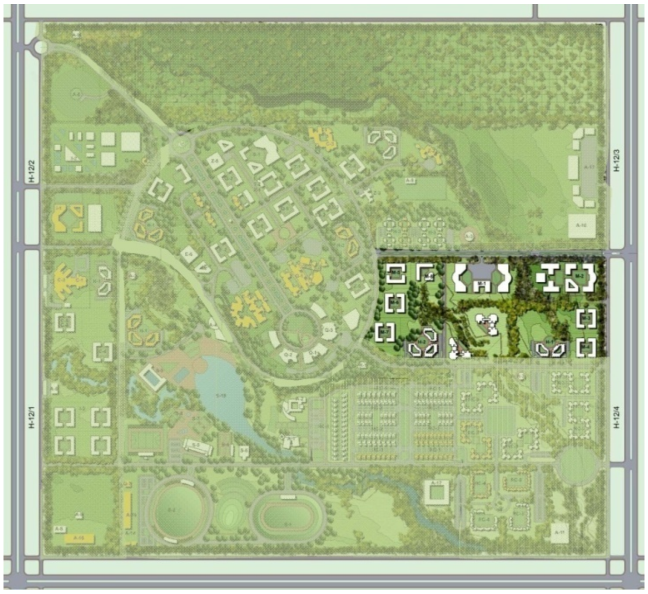

Figure 4.5 Zone 5- NUST Medical Complex

The area shown in figure 4.5 is dedicated to the NUST medical complex. The idea of complex is around a teaching hospital of five hundred beds with related amenities. However at west of the complex lies the girls hostel and on the far-east lies the information/ reception building. The area is mostly undeveloped as the hospital complex is yet to be built.

Figure 4.6 Zone 6- Botanical Garden

Ninety percent of the area for zone 6 is would ultimately be converted into a botanical garden however few structures exist on the south eastern side of the zone which are schools and hostel for married students. Most of the structures for this zone are already built and operating (figure 4.6).

4.4 DATA COLLECTION

Seventh part of the nine step model is the data collection process. Data was collected from two sources majorly 1. National Engineering Services (NESPAK) who are the consultants for the entire master planning for this new campus 2. The project management division of National University of Science & Technology (NUST) which operates from within this new campus and is responsible for the construction works. A copy of the proposed and current master plan was obtained from these sources to check and verify the areas currently and after completion. Auto cad was the software used to calculate area for each zone pertaining to Buildings roof, Pavements (roads, sidewalks and parking) and the remaining area fell into the category of Green area regardless it is landscaped or still undeveloped barren area. Once the area for each type of surface within the zone is calculated it is incorporate into the rational formula. The data is evaluated based on the rational formula method as explained in previous chapter;

"Q=KCIA", where K is the local adjustment factor and A being the study area remaining variables are explained in detail below

4.4.1 RUNOFF COEFFICIENT

Run off coefficient explains the ability of a surface to let the water pass through its surface without percolating in. Every surface has a different run off coefficient based on its permeability and how pervious that surface is. The co efficient taken here in this study are of only three surfaces based on the ten to hundred years of data by Steel and McGhee (1997);

- Building roofs 0.86,
- Pavements 0.915 and
- Green area 0.2;

  These figures represents percentage of water that flow as run off over these surfaces for example 86% of water falling on building roofs would come out as runoff, similarly pavements and roads being most impervious shows that almost 92% water flows.

4.4.2 RAINFALL INTENSITY

As part of the rational formula method, rainfall intensity "I" is one of the governing factor to evaluate the rate of runoff. One needs to know the rainfall patterns of the selected study area. The rainfall intensity, I, is the average rainfall rate in inches per hour for the period of maximum rainfall. The month for maximum average rainfall is considered as basic criteria for calculation. The figure 4.7 below shows the annual rainfall data for Pakistan.

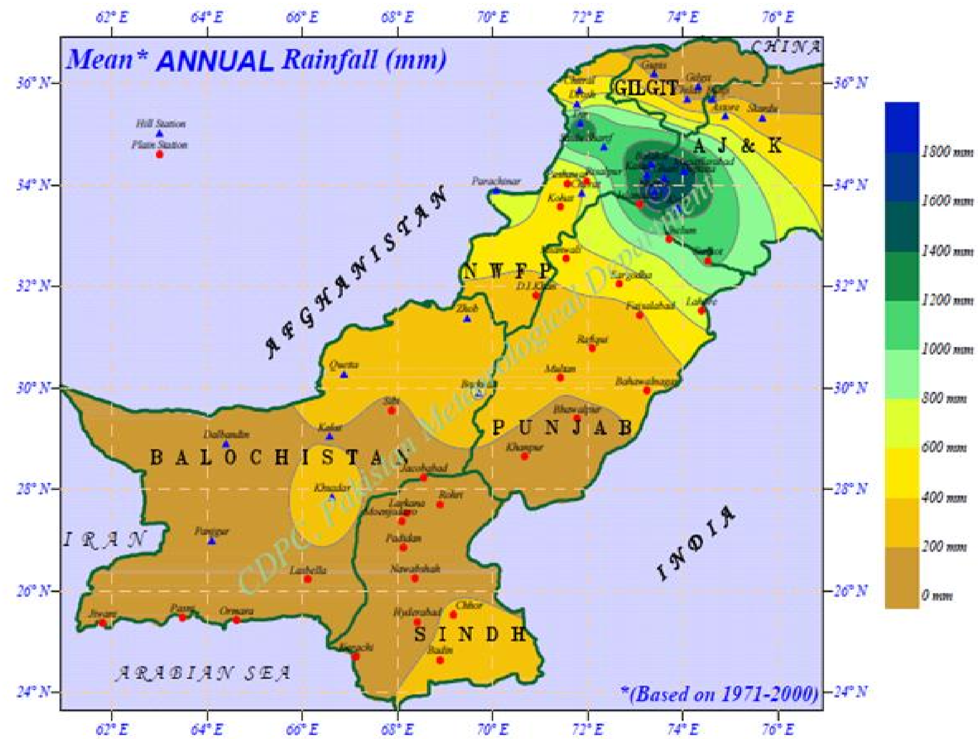

Figure 4.7 Pakistan Mean Annual Rainfall (Adopted from: Pakistan Metrological Department)

4.5 PROPOSED WATER RECLAMATION PROCESS

The figure 4.8 explains a specific rainwater collection system well integrated into the whole site design. The system for water collection is simple consisting of storm drains along the road and along building plinths. The water is collected from building roofs through rainwater pipes which will eventually fall into the storm drainage pipes. Similarly the drains along the road would collect water from road and paved surfaces to eventually dispose in the main drain. Most of the structure regarding to drains is already present but the ultimate disposal is inefficient as it all goes into the city sewer. These drains for each zone would have an independent water filtration and storage tanks. Before entering into the water storage tanks the collected storm water would go through filtration process to remove pollutants. The cleaned water would than enter the storage tank which will then be pumped up to the overhead water tanks on each building. By this way we would not only reduce the waste water contribution to city sewer; which leads to a high treatment cost but would save significant amount of fresh water. Figure 4.8 identifies the location of various underground water tanks placed in the natural shallow areas of each zone so the water may travel through gravity to avoid any mechanical mechanism to collect. Similarly the thick border lines are roads which mark the limit of each zone. This way each zone would become more independent and would be easier to manage and maintain.

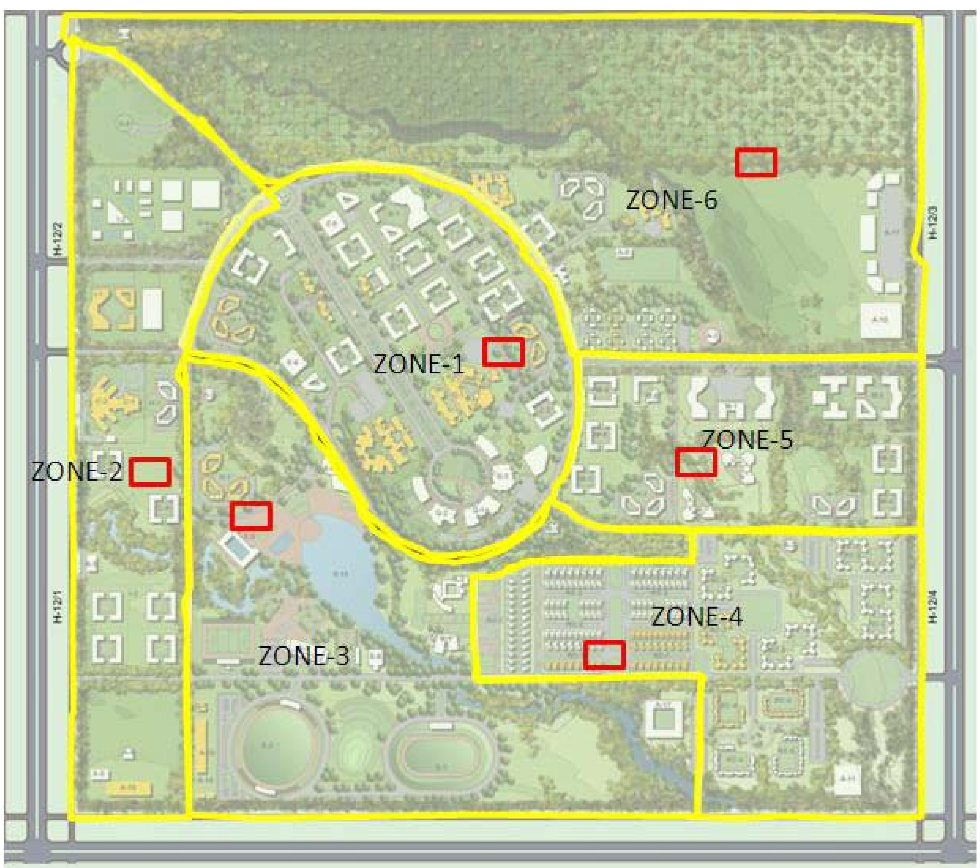

Figure 4.8 Underground Storm Water Tanks for each Zone

4.6 SUMMARY

In this chapter complete site is studied and evaluated for its ability and potential for being the proper case study. The chapter starts by constructing the validity of the case study selected by explaining the advantages and reason of selecting this particular site. The reason for selecting an Institutional complex was the varying characteristic it offers within one compound and a huge number of occupants coming in here every day makes it a highly likely place not just for the study but training purposes also. NUST has a diverse nature in terms of the various functions happening here. The site is a representation of a small city with all basic amenities thus a model successful here is likely to be successful in any multi use complex. Comprehensive picture of National University of Science and Technology is given and the whole site is divided into six smaller zones. Zones are named after their functionality like residential area depicting all residences, condominiums, houses etc. Similarly science and technology contains academic blocks related to science studies and so on. Characteristic of each zone is explained and the advantages of zoning highlighted. The chapter distinguished the case study from alternate research strategies. Logic to data collection approach is developed and strategy advised which is further explained in the following chapter with more precise results.

CHAPTER 5

RESULTS ANALYSIS AND DISCUSSIONS

5.1 INTRODUCTION

There are three independent variables on the basis of which the data is evaluated. The change and variation in these would lead to changing results and responses. As explained earlier in previous chapter the NUST campus is divided into six zone and each zone is further categorize into three different kind of surfaces Residential/Roofs, Pavements and Green area. The basis of this division is the varying amount of runoff water they produce with same amount of rain at a given time. Figure 5.1 shows the NUST master plan 2008 with all six zones highlighted by different colours; Zone 1(IT and Science & Tech), Zone 2 (CE & Tech Park), Zone 3(Lake & Sports Complex), Zone 4(Residential), Zone 5(NMC), Zone 6(Botanical Garden).

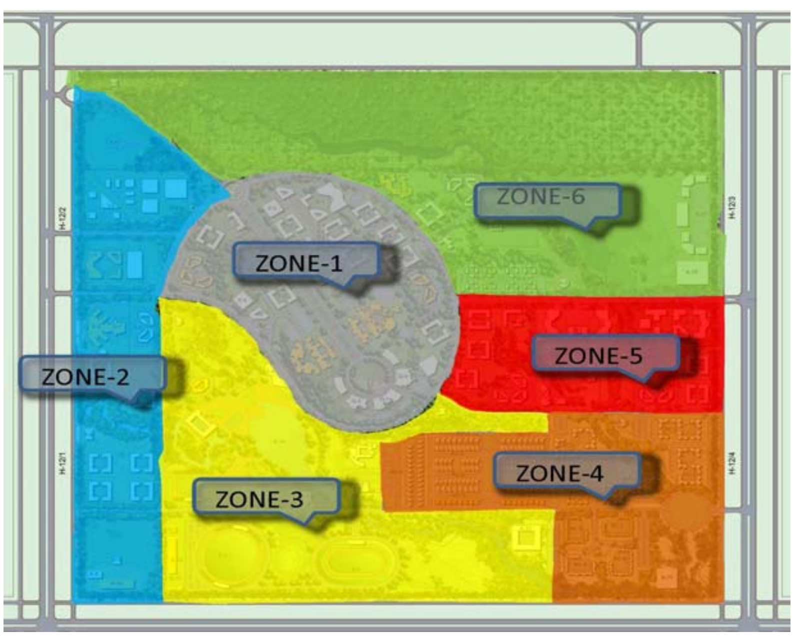

Figure 5.1 NUST Master Plan 2008-Zoning

5.2 DESCRIPTIVE ANALYSIS

Descriptive statistics summarises the collected data and presents in the most scientific way. The descriptive analysis is generally supported by line diagrams, graphs, bar charts, pie chart and histograms. The data here was collected by means of survey and use of technological software Auto Cad. The latest master plan developed by National Engineering Services for National University of Science & Technology, H-12 Campus was used for the calculation of entire university areas and with the help of satellite images and personal visits the current developments were marked.

The area was primarily divided into six zones, each zone was than further categorized into three types as Building roof area, Pavement area and the remaining Green or Undeveloped land. The distinction is made based on the characteristic of each surface for the amount of runoff it can produce. The rationale method identified in Hydrologic Criteria and Drainage Design Manual is used to calculate the runoff coefficient and the amount of runoff. The runoff water is calculated in cubic meter and then converted into gallons of water to observe the amount of non potable water produced. The comparison between the 2008 master plan which shows the complete campus development till 2020 and the current development level till April 2011 is made to see the direct proportionality of the increase in runoff with increase in infrastructure development. The amount of storm water generated as of now and then is calculated and presented.

5.2.1 QUANTIFYING RUNOFF WATER FOR NUST MASTER PLAN 2008

All six zones are evaluated for the amount of Runoff water produced by first calculating the area of respective surfaces. As each surface has varying property of producing runoff with same amount of rainfall. Runoff produced by the buildings is through the roofs, by pavements is through the asphalt roads, sidewalks and parking lots and by green means developed landscape and the barren area. Although as per NUST master plan 2008 entire campus would be developed along with all leftover spaces turned into designed landscape spaces.

Table 5.1 shows the area ratio of Buildings, Pavements and Green within each zone. The areas are formulated in square meter to be easily used in the rational method formula. The table clearly identifies the biggest zone to be Zone six the Botanical garden which lies in the North East of the campus. The zone would facilitate not just the medical students in Zone 5 but also acts as a buffer zone between the main campus and the dual carriage highway which leads to the state of Kashmir. This is followed by Zone 3 being the second biggest. The zone has been designed to hold sport activities having cricket, football stadiums with indoor sports gymnasium and a lake in the centre. Zone 3 is a low lying area of the campus and most of the water naturally flows into this area which may be collected in this lake for reuse and can act as a reservoir for emergency reserves. The lake area is not indicated separately but shown as part of Green.

Table 5.1 Building Pavement Greenery Area’s

Zone Name	**Area Name**	**Building Roof Area (sq.m)**	**Pavement Area(sq.m)**	**Greenery Area(sq.m)**	**Total of Zones (sq.m)**
Zone 1	I.T & ST	52063	200526	97336	349925
Zone 2	CE & Tech Park	41174	52285	245238	338254
Zone 3	Lake & Sports Complex	19486	101784	373110	494380
Zone 4	Residential	46968	108190	167829	322987
Zone 5	NMC	97905	49857	64963	212725
Zone 6	Botanic Garden	25268	33056	623287	681611

A percentage representation of all surface area is shown in figure 5.2. Zone 1 has the lowest green area percentage as most of the zone is hard paved with asphalt roads and pavers (58%) which hardly allow water to penetrate. Rest of the area is occupied with Buildings mostly Academic buildings and a few student residences. Zone 5 has the highest building percentage of 45 with 30% green area and 24% of paved area. Zone three and zone six has the lowest percentage of building area 4% with most of the area planned to be kept as open land.

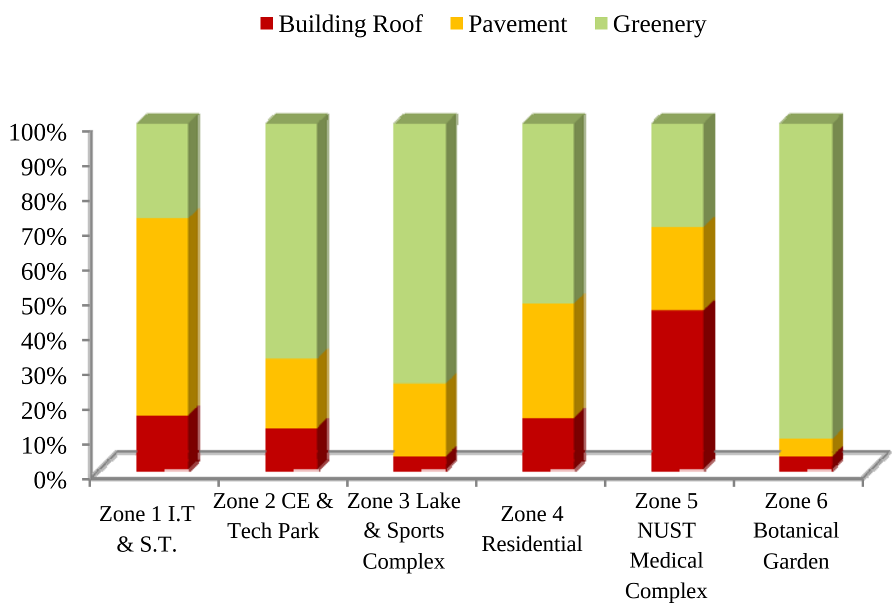

Figure 5.2 Percentage of building, pavement & green area

Figure 5.3 represents the similar picture with a comparison of Areas for all three types of surfaces within each zone. The towering green bars clearly shows the prominent green surfaces in each zone except for zone 1 and zone 5 which have higher value of paved and building areas respectively. The runoff coefficient for each surface varies depending upon infiltration, evaporation, retention and flow routing of each surfaces. The asphalt roads and pavements produce the highest runoff followed by building roofs and the green area. Some of the standard average percent impervious values for each surface used are Building roofs 0.86, Pavements 0.915 and Green area 0.2; based on the average data of ten to hundred years as discussed in chapter 3 and 4.

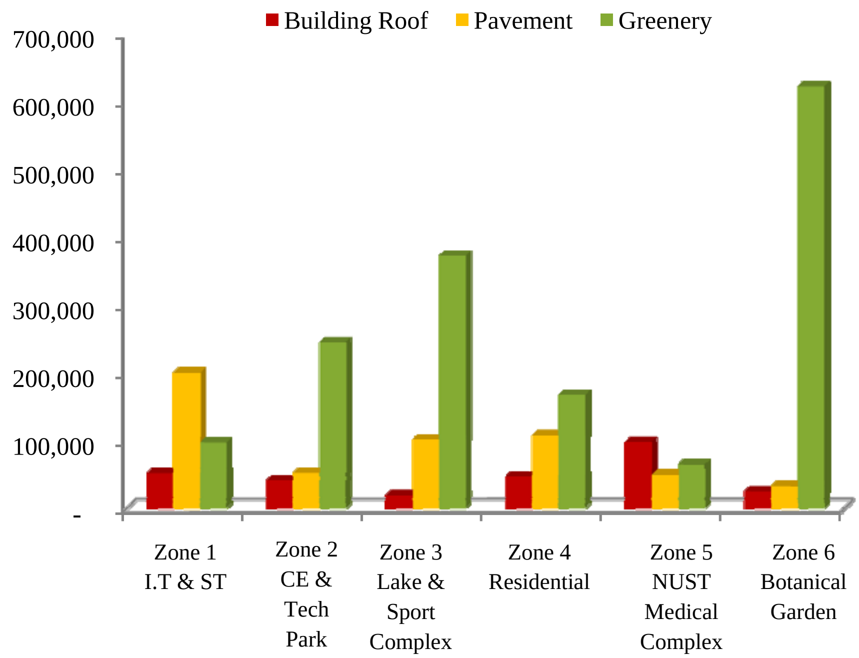

Figure 5.3 Comparison of building, pavement & green area

Composite runoff coefficient is required to calculate the actual runoff generated by each zone. For that purpose each zone's surfaces area are multiplied by respective impervious percent and divided by the total area, as shown in table 5.2. Each zone comes out with a different Runoff coefficient depending upon the area of each varying surface.

Table 5.2 calculates the runoff coefficient by using Rational Method Formula as discussed in chapter 3. This primarily depends upon the area of each zone, the composite runoff coefficient and the rainfall intensity.

Table 5.2 Computation for Composite Runoff Coefficient

Zone Name	**Area Name**	**Building Roof Area (sq.m)**	**Pavement Area(sq.m)**	**Green Area(sq.m)**	**Total of Zones (sq.m)**	**Composite Runoff Coefficient "C"**
Zone 1	I.T & ST	52063	200526	97336	349925	0.71
Zone 2	CE & Tech Park	41174	52285	245238	338254	0.39
Zone 3	Lake & Sports Complex	19486	101784	373110	494380	0.37
Zone 4	Residential	46968	108190	167829	322987	0.54
Zone 5	NMC	97905	49857	64963	212725	0.67
Zone 6	Botanic Garden	25268	33056	623287	681611	0.26

Table 5.3 gives the amount of storm runoff produced by each zone in cubic meter per second. The rainfall intensity is the highest average rainfall per hour in a year as shown in figure 4.7 of previous chapter. The information is graphically represented in the figure 5.4 showing the storm runoff produced by each zone in gallons.

Table 5.3 Runoff Calculation by Rational Method

Zone Name	Area Name	Area (sq.m)	Area (sq.km)	Runoff Coefficient "C"	Intensity (mm/hr)	Runoff (cu.m/ sec)
Zone 1	I.T & ST	349925	0.35	0.71	0.4	0.03
Zone 2	CE & Tech Park	338254	0.34	0.39	0.4	0.016
Zone 3	Lake & Sports Complex	494380	0.49	0.37	0.4	0.022
Zone 4	Residential	322987	0.32	0.54	0.4	0.021
Zone 5	NMC	212725	.21	0.67	0.4	0.017
Zone 6	Botanical Garden	681611	.68	0.26	0.4	0.02

The figure 5.4 clearly indicates that the amount of storm water produced does not depend upon the total area of the zone but how impervious the surfaces in it are and how much is the area covered by these surfaces. The NUST campus has a total water storage capacity of sixteen hundred thousand Gallons; having two overhead water tanks each of hundred thousand gallon with an underground water capacity of fourteen hundred thousand gallons. The total amount of storm water runoff produced as per figure 5.4 is 120777 which makes 8% of the total water requirement of the entire campus of NUST. This means a reasonable saving on the potable water which may be used for non potable purposes like Toilet Flushing, Landscaping, Car washing, water for Chillers, boilers, etc.

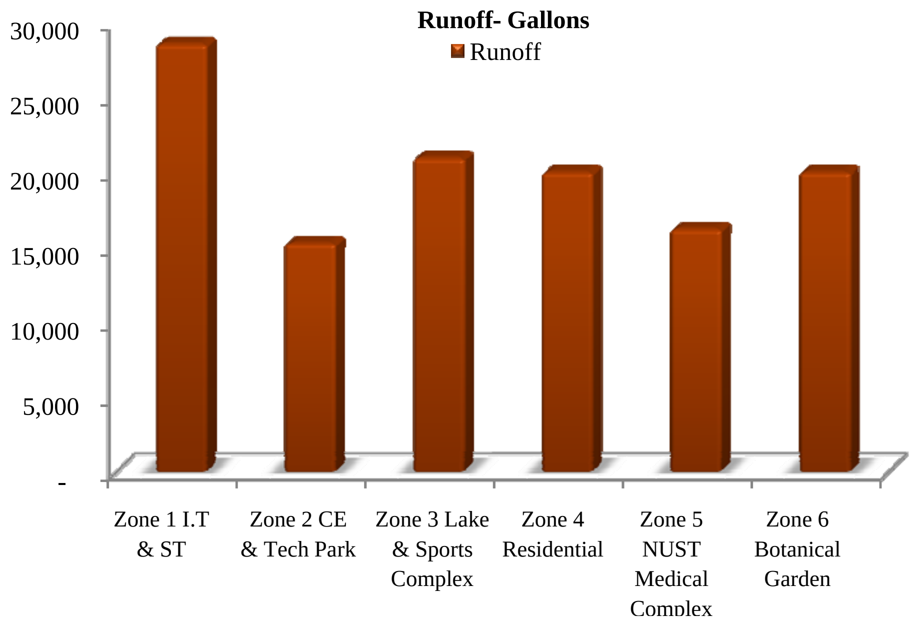

Figure 5.4 Storm water generated by each zone

5.2.2 QUANTIFYING RUNOFF WATER FOR CURRENT DEVELOPMENT

All six zones are evaluated for the amount of Runoff water produced in the similar fashion. Runoff produced by the buildings is through the roofs, by pavements is through the asphalt roads, sidewalks and parking lots and by green means developed landscape and the barren area. Current situation reflects the study of areas based upon the current development till April 2011.

Table 5.4 shows the area ratio of Buildings, Pavements and Green within each zone. The areas are formulated in square meter to be easily used in the rational method formula. The table clearly identifies the varying areas of three main components; buildings, pavements and green; however the overall area remains the same. The built up area in most of the zones is significantly low thus an increased green or undeveloped area is observed. The built up area of each Zone varies in comparison of table 5.1 as the development is under way and the values would go on changing with the development patterns. For example, In contrast to table 5.1 the below table 5.4 shows us that Zone 5 has the lowest building roofs area as the construction work hasn't started there yet, however would eventually become the zone with largest building area. This means that most of the rain water would percolate into the ground thus producing the lowest value of runoff as shown in figure 5.7.

Table 5.4 Building Pavement Greenery Area's-Current Development

Zone Name	Area Name	Building Roof Area (sq.m)	Pavement Area(sq.m)	Greenery Area(sq.m)	Total of Zones (sq.m)
Zone 1	I.T & ST	31308	198295	120322	349925
Zone 2	CE & Tech Park	13484	46440	277965	338254
Zone 3	Lake & Sports Complex	5980	48676	439724	494380
Zone 4	Residential	8918	34653	279416	322987
Zone 5	NMC	3114	14062	195549	212725
Zone 6	Botanic Garden	6559	20402	654650	681611

A percentage representation of all surface area is shown in figure 5.5. Zone 1 has the lowest green area percentage as most of the zone is hard paved with asphalt roads and pavers (57%) which hardly allow water to penetrate. Rest of the area is occupied with Buildings mostly Academic buildings and a few student residences and zone 6 has the highest percentage of Green or undeveloped area. Zone 6 didn't show significant change as most of the land in it would remain green.

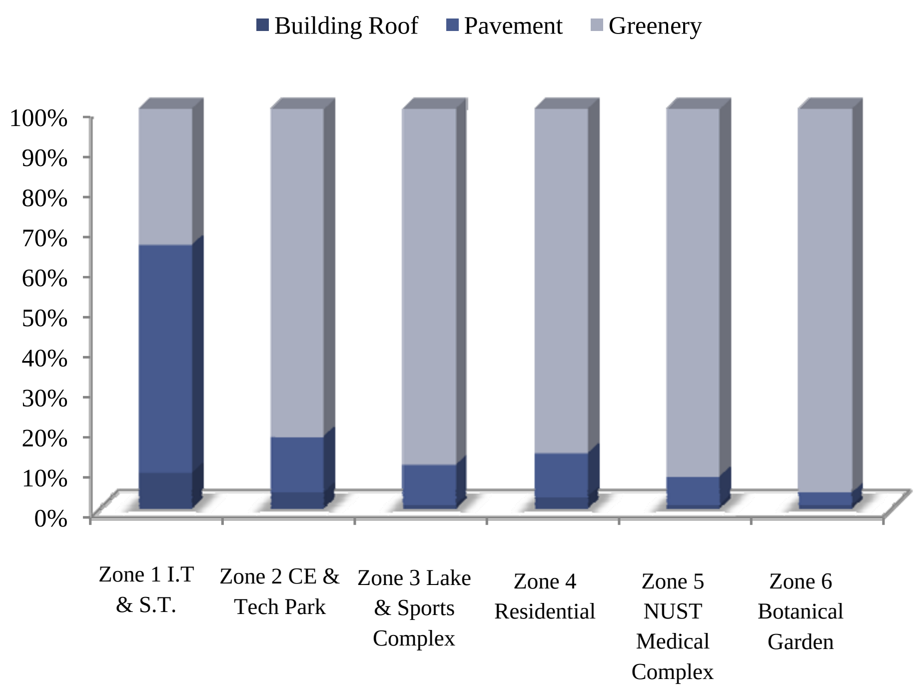

Figure 5.5 Percentage of building pavement green area-current development

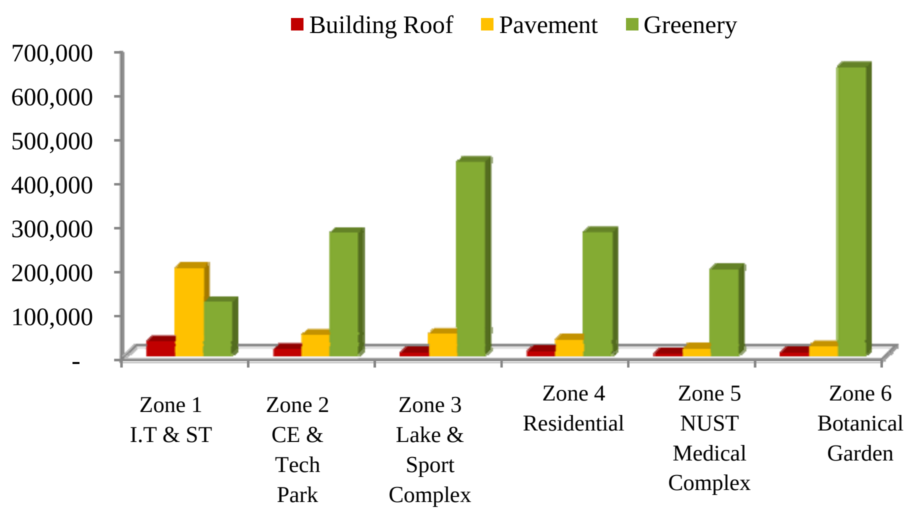

Figure 5.6 Comparison of Building Pavement & Green Area-Current Development

Figure 5.6 represents the similar picture with a comparison of Areas for all three types of surfaces within each zone. The towering green bars clearly shows the prominent green surfaces in each zone except for zone 1 which has higher value of paved and building areas respectively. The runoff coefficient for each surface varies depending upon infiltration, evaporation, retention and flow routing of each surfaces. The asphalt roads and pavements produce the highest runoff followed by building roofs and the green area. Some of the standard average percent impervious values for each surface used are Building roofs 0.86, Pavements 0.915 and Green area 0.2; based on the average data of ten to hundred years (Steel and McGhee 1997).

Composite runoff coefficient is required to calculate the actual runoff generated by each zone. For that purpose each zone's surfaces area are multiplied by respective impervious percent and divided by the total area, as done previously is shown in table 5.5. Each zone comes out with a different Runoff coefficient depending upon the area of each surface.

Table 5.5 calculates the runoff coefficient by using Rational Method Formula as discussed in chapter 3. This primarily depends upon the area of each zone, the composite runoff coefficient and the rainfall intensity.

Table 5.5 Computation for Composite Runoff Coefficient-Current Development

Zone Name	Area Name	Building Roof Area (sq.m)	Pavement Area(sq.m)	Green Area(sq.m)	Total of Zones (sq.m)	Composite Runoff Coefficient "C"
Zone 1	I.T & ST	31308	198295	120322	349925	0.66
Zone 2	CE & Tech Park	13484	46440	277965	338254	0.32
Zone 3	Lake & Sports Complex	5980	48676	439724	494380	0.28
Zone 4	Residential	8918	34653	279416	322987	0.29
Zone 5	NMC	3114	14062	195549	212725	0.26
Zone 6	Botanic Garden	6559	20402	654650	681611	0.23

Table 5.6 Runoff Calculation by Rational Method-Current Development

Zone Name	**Area Name**	**Area (sq.m)**	**Area (sq.km)**	**Runoff Coefficient "C"**	**Intensity (mm/hr)**	**Runoff (cu.m/ sec)**
Zone 1	I.T & ST	349925	0.35	0.66	0.4	0.028
Zone 2	CE & Tech Park	338254	0.34	0.32	0.4	0.013
Zone 3	Lake & Sports Complex	494380	0.49	0.28	0.4	0.017
Zone 4	Residential	322987	0.32	0.29	0.4	0.011
Zone 5	NMC	212725	.21	0.26	0.4	0.007
Zone 6	Botanic Garden	681611	.68	0.23	0.4	0.019

Table 5.6 gives the amount of storm runoff produced by each zone in cubic meter per second. The information is graphically represented in the figure 5.7 showing the storm runoff produced by each zone in gallons.

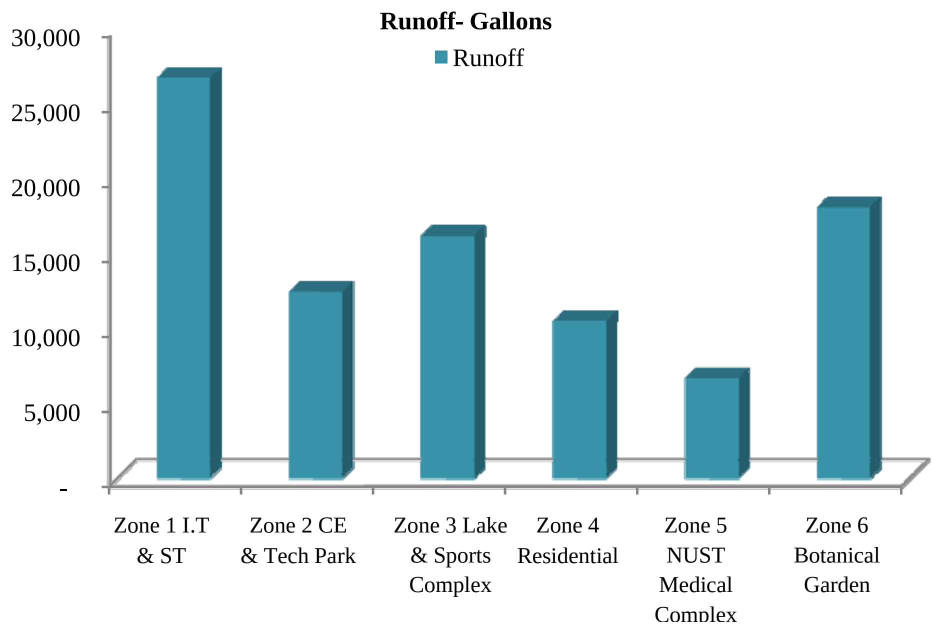

Figure 5.7 Storm water generated by each zone-current development

The figure 5.7 shows that the amount of storm water produced does not depend upon the total area of the zone but how impervious the surfaces in it are and how much is the area covered by these surfaces. The NUST campus has been designed to store sixteen hundred thousand Gallons of water; having two overhead water tanks each of hundred thousand gallon with an underground water capacity of fourteen hundred thousand gallons. Currently NUST water supply is based on nine tube-wells; out of which seven are operating at an average rate of 3000 gallons of water extracted per hour in order to meet the current requirement of 550,000 gallons of water. Remaining two tube-wells are not able to extract water as water table has already depleted.

The total amount of storm water produced as per figure 5.7 is 90447 gallons a day, which makes 16% of the total water requirement of the entire campus of NUST currently. This means a significant saving on the potable water which is being used for non potable purposes like Toilet Flushing, Landscaping, Car washing, water for Chillers, boilers, etc.

The study helps us identify that as the built environment increases the water runoff also increases, which makes them directly proportional. However one of the disadvantages is that with the growing infrastructure less water percolates into the ground, thus not allowing the ground water to recharge and depleting the ground water table. The reuse of water would require less water to be extracted from the ground supporting sustainable use of water resource.

5.3 SUMMARY

This chapter quantifies the amount of water that would be available for reuse. Two different scenarios have been discussed above and subsequently two different results extracted. The first calculation is done assuming the complete build out of the NUST campus. Areas are extracted for each zone incorporating roads, pavements and building rooftops: which includes the one already build and the ones which are part of the complete master plan. Using the rationale formula method water is quantified that would be generated as a result of rain or storm. In this case it is calculated that one hundred and twenty thousand seven hundred seventy seven (120777) gallons of water would be available for reclamation per day that makes eight percent of entire water requirement of NUST. However in the other scenario calculations were made for the current situation as of April 2011 and water was quantified in similar fashion using the rationale formula for quantifying storm water. Ninety thousand four hundred and seventy seven (90477) gallons are estimated to be available each day with current level of infrastructure available. This makes sixteen (16%) of the entire water requirement of NUST which is currently fulfilled by groundwater extraction through tube wells. It is evident from the analysis above that the amount of water generated by each zone does not depend upon the area of that zone but on the characteristic of the surfaces in it. The more impervious the surfaces are the more is the amount of runoff produced.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSIONS

Ground water depletion is hitting various sectors of Islamabad including sector H-12 which is dedicated to educational facility of National University of Science & Technology. This depleting condition is primarily due to weak legislation and current water usage patterns. This study focuses on the water resource management through efficient reuse strategy. Calculations have been made and analysed for the amount of water that can be collected for different zones and how it contributes towards sustainable development.

The depleting water table at National University of Science & Technology is evident from the fact that out of nine tube-wells only six are currently working. The remaining three have become un-productive as water level has fallen below the boring level; and out of these six only two are extracting water at the full capacity. Use of reclaimed rainwater is an efficient and much needed response in this situation. Induction of a rainwater system may have a higher capital cost but a much competitive life cycle cost.

Reuse of water and meeting the objective of non potable use by non potable means is an advanced level of Sustainable development and a higher degree of environmental gain. By adopting the strategy of rain water harvesting and grey water reuse NUST would not only become a pioneer facility in Islamabad to do so but a platform for educating the masses to become environmentally responsive citizens. Storm water re use does not necessarily involves hi tech equipment or some state of the art technology it can be a pretty simple system, however can make significant difference.

The study here reveals the amount of storm water that can be saved and stored in each zone. The calculations are based on three different types of surfaces 1) Building roofs, 2) Roads and Pavements & 3) Green/ open area based on their varying properties; within each zone. Amount of water generated in each zone gives us a fair enough idea of how much potable water can be saved.

6.2 RECOMMENDATIONS

Infiltration planters can be added in pavements at regular interval along road. These planters may have sand and pebbles at the base to collect and filter the storm runoff from roads and pavements and then pass it on to the main drain.

In addition to above option, rainwater can be collected and stored separately from the roof top with a collection cistern there and let the water flow through gravity.

NUST infrastructure is designed and constructed in a way that it collects the road water through open drains along the roads and covered drains for the open or landscaped area and rainwater downspouts which collect the roof rain water. Unfortunately this water is finally discharged into the main drains and ultimately into sewer pipes as waste water. The need is only to have this water collected in tanks where this water can be stored for reuse and a mechanism to supply this water to the buildings non potable water required functions for non potable use.

Another most useful aspect is the use of *Grey water*; water that comes out of the wash basins, showers and dish washers can be reused with a little more treatment than storm water. This form of water would be huge source of supply as every household; every department and every office is producing such waste every day. Reuse of Grey water would make a significant contribution in case of Hostels, apartments and multi-storey buildings.

6.3 FUTURE DIRECTIONS

The scope of this thesis included the survey and study of National University of Science & Technology’s H-12 campus, Islamabad. It primarily focuses on water reuse strategies to achieve Sustainable development. However

Water Efficiency is one basic part of achieving sustainable development it may also include materials & resource, indoor environmental quality, sustainable sites, energy and atmosphere, etc.

Research may be carried out for NUST's new campus to suggest means and measures to be GREEN and achieve higher standards of LEED and other global certification for Sustainable Construction practices.

Study can be further stretched to suggest *Green Roofs*; which would control the roof runoff and work as building roof top insulations. Thus reducing the air-conditioning requirement of the facility and providing an open landscaped area on top.

Alternate options to cut down conventional energy reuse and make the facility sustainably efficient may be explored like *geothermal energy* for heating and cooling the buildings. As earth crust at certain depth maintains its temperature; so air can be passed through it for heat exchange and can then be pulled out for supply. *Heat Drilling* is also an example of geothermal energy use.

Sewer Heat exchange is another way of extracting heat from the sewer lines by a closed loop system running in the crust of main sewer lines.

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APPENDICES

Appendix 1: Zone 1- Area Schedule

ZONE - 1 (I.T. and S.T.)						
	BUILDING / STRUCTURE			**ROADS & PAVEMENTS**		**GREEN**
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Pavement Area-Sft**	**Green Area-Sft**
1	E-1	SEECS	70288	Indus Loop	308050	1047754
2	E-2	IAEC	20552	Part-Bolan Road	52500	
3	E-3	RCMS	7616	Scholars Avenue	1317610	
4	E-4	RIMMS	7616	Others	480355	
5	E-5	IGIS	14321			
6	E-6	CB/HPCF	12590			
7	E-7	Concordia-2	12553			
8	H-1	Boys Hostel(Rumi)	28740			
9	H-2	Girl's Hostel(Fatima)	19160			
10	G-1	NIMS/NBS	79277			
11	G-2	CAMP	20552			
12	N-7	Not Constructed	20552			
13	N-8	Not Constructed	20552			
14	SS-1	Not Constructed	20552			
15	SS-2	Not Constructed	20552			
16	SS-3	Not Constructed	20552			
17	Q-1	Nust Head Quarter	23207			
18	Q-2	Not Constructed	16396			
19	Q-3	Not Constructed	20580			
20	Q-4	Not Constructed	12066			
21	M	Mosque	9425			

22	Z-5	Not Constructed	17911			
23	Z-6	Not Constructed	20552			
		NVI	22128			
		SADA	22128			
	TOTAL		**560418**		**2158515**	**1047754**
	In Square meters		**52063**		**200526**	**97336**

Total Area of Zone 1 is **349925 Sqm**

Appendix 2: Zone 2- Area Schedule

ZONE - 2 (C.E & Tech Park)						
	BUILDING / STRUCTURE			ROADS & PAVEMENTS		GREEN
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	C-1	CCE	41673	Aligarh Avenue	122625	2467790
2	C-2	NIT	53140	Part-Indus Loop	58113	
3	C-4	IUPA	33900	Bolan Road	105883	
4	C-5	NEEC	10210	Others	276186	
5	C-6	IGWMH	10210	Helipad	167252	
6	B-1	IAE	20422			
7	B-2	IPE	20422			
8	B-3	IME	20422			
9	H-1	Boys Hostel Ghazali	19160			
10	H-1	Boys Hostel	28740			
11	I-1	TIC	9824			
12	I-2	Nust Consultation	17706			
13	I-3	Technology Park	49589			
14	N-3	NIT-Ext	17249			
15	Q-6	PDO	4081			
16	Z-6	FPGI	81688			
17	A-11	Water Tank	4767			
	TOTAL		**443203**		**730059**	**2467790**
	In Square meters		**41174**		**67822**	**229258**

Total Area of Zone 2 is 338254 Sqm

Appendix 3: Zone 3- Area Schedule

ZONE - 3 (Lake & Sports Complex)						
	BUILDING / STRUCTURE			**ROADS & PAVEMENTS**		**GREEN**
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	A-1	Club House	18598	Volleyball Court	15077	4006670
2	A-5	Campus Mosque	9634	Basketball Court	24285	
3	A-6	Student Café	15347	Tennis court	33578	
4	A-13	School	57582	Squash Court	12523	
5	H-1	Boys Hostel	38320	Hockey Stadium	119934	
6	R-1	Not Constructed	5174	Cricket Stadium	192082	
7		Halls	27548	Football Stadium	174194	
8		Printing Press	19155	Main road	222775	
9		DPC	5361	Others	301187	
10		Addition Living	11112			
11		Not Constructed	11503			
	TOTAL		**219334**		**1095635**	**4006670**
	In Square meters		**20376**		**101784**	**372220**

Total Area of Zone 3 is **494380 Sqm**

Appendix 4: Zone 4- Area Schedule

ZONE - 4 (Residential Colony)						
	BUILDING / STRUCTURE			ROADS & PAVEMENTS		GREEN
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	A-5	Community Mosque	9634	Other	11286	1806553
2	RC-1	Houses	144880		78603	
3	RC-2	Houses	164736		64812	
4	RC-3	Apartments	132840		107568	
5	RC-4	Apartments	28848		8680	
6	RC-5	Apartments	24640		22969	
7					31844	
8					48080	
9					61941	
10					85896	
11					21824	
12					57868	
13					48172	
14					55818	
15				Residence pavements	459228	
	TOTAL		**505578**		**1164589**	**1806553**
	In Square meters		**46968**		**108190**	**167829**

Total Area of Zone 4 is **322987 Sqm**

Appendix 5: Zone 5- Area Schedule

ZONE - 5 (NUST Medical Complex)						
	BUILDING / STRUCTURE			ROADS & PAVEMENTS		GREEN
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	H-1	Boys Hostel	19160	Ravi Road	113942	694496
2	H-2	Girl Hostel (Zainab)	38320	Khyber Road	37420	
3	H-2	Girl Hostel	28740	Other	385315	
4	M-1	CMS	64666			
5	M-2	Hospital	860888			
6	M-3	IP	20420			
7	M-4	IP	20420			
8	M-7	RCMS	20420			
9		Unnamed	6I554			
10	N-12	Nust Info Center	4778			
	TOTAL		**1058652**		**536677**	**694496**
	In Square meters		**98349**		**49857**	**64519**

Total Area of Zone 5 is **212725 Sqm**

Appendix 6: Zone 6- Area Schedule

ZONE - 6 (Botanical Garden)						
	BUILDING / STRUCTURE			**ROADS & PAVEMENTS**		**GREEN**
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	A-11	Water Tank	4791	Luqman Avenue	175314	6709224
2	C-3	IESE	37648	Other	180514	
3	H-3	MSH	83944			
4	N-5	Biseater Hostel	28740			
5	N-11	Mosque	51109			
6	S-15	Golf House	18534			
7	Z-1	CCT & SM	8016			
8	Z-2	SCME	18790			
9	Z-4	REI	20420			
	TOTAL		**271992**		**355828**	**6709224**
	In Square meters		**25268**		**33056**	**623287**

Total Area of Zone 5 is **681611 Sqm**

Appendix 7: Zone 1- Area Schedule (Till April 2011)

ZONE - 1 (I.T. and S.T.) -APRIL 2011						
	BUILDING / STRUCTURE			**ROADS & PAVEMENTS**		**GREEN**
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Pavement Area-Sft**	**Green Area-Sft**
1	E-1	SEECS	70288	Indus Loop	308050	1295179
2	E-3	RCMS	7616	Part-Bolan Road	52500	
3	E-4	RIMMS	7616	Scholars Avenue	1317610	
4	E-5	IGIS	14321	Others	456337	
5	E-7	Concordia-2	12553			
6	H-1	Boys Hostel(Rumi)	28740			
7	H-2	Girl's Hostel(Fatima)	19160			
8	G-1	NBS	79277			
9	SS-1/Café	Concordia-1	20552			
10	Q-1	Nust Head Quarter	23207			
11	M	Mosque	9425			
12		NVI	22128			
13		SADA	22128			
	TOTAL		**337011**		**2134497**	**1295179**
	In Square meters		**31308**		**198295**	**120322**

Total Area of Zone 1 is **349925 Sqm**

Appendix 8: Zone 2- Area Schedule (Till April 2011)

ZONE - 2 (C.E & Tech Park)-APRIL 2011						
	BUILDING / STRUCTURE			ROADS & PAVEMENTS		GREEN
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1				Aligarh Avenue	122625	2992093
2	C-2	NIT	53140	Part-Indus Loop	58113	
3	B-2	IPE	20422	Bolan Road	105883	
4	B-3	IME	20422	Others	213273	
7	H-1	Boys Hostel Ghazali	19160			
8	I-1	TIC	9824			
9	N-3	NIT-Ext	17249			
11	Q-6	PDO	4081			
14	A-11	Water Tank	4767			
	TOTAL		**149065**		**499894**	**2992093**
	In Square meters		**13848**		**46440**	**277965**

Total Area of Zone 2 is **338254 Sqm**

Appendix 9: Zone 3- Area Schedule (Till April 2011)

ZONE - 3 (Lake & Sports Complex)-APRIL 2011						
	BUILDING / STRUCTURE			**ROADS & PAVEMENTS**		**GREEN**
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
5	H-1	Boys Hostel	28740	Main road	222775	4733309
8		Printing Press	19155	Others	301187	
9		DPC	5361			
10		Addition Living	11112			
	TOTAL		**64368**		**523962**	**4733309**
	In Square meters		**5980**		**48676**	**439724**

Total Area of Zone 3 is **494380 Sqm**

Appendix 10: Zone 4- Area Schedule (Till April 2011)

ZONE - 4 (Residential Colony)-APRIL 2011						
	BUILDING / STRUCTURE			ROADS & PAVEMENTS		GREEN
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
2	RC-1	Houses	14488	MI room	6736	3007709
3	RC-2	Houses	24960	Other	115752	
4	RC-3	Apartments	22140		85330	
5	RC-4	Apartments	10812		38400	
6	RC-5	Apartments	5390		17233	
7	Block 1,2,3	Apartments	13986		11286	
8		MI room	4225		22514	
9					29044	
10					46715	
	TOTAL		**96001**		**373010**	**3007709**
	In Square meters		**8918**		**34653**	**279416**

Total Area of Zone 4 is **322987 Sqm**

Appendix 11: Zone 5- Area Schedule (Till April 2011)

ZONE - 5 (Nust Medical Complex)-APRIL 2011						
	BUILDING / STRUCTURE			ROADS & PAVEMENTS		GREEN
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	H-2	Girl Hostel (Zainab)	28740	Ravi Road	113942	2104945
2	N-12	Nust Info Center	4778	Khyber Road	37420	
	TOTAL		**33518**		**151362**	**2104945**
	In Square meters		**3114**		**14062**	**195549**

Total Area of Zone 5 is **212725 Sqm**

Appendix 12: Zone 6- Area Schedule (Till April 2011)

ZONE - 6 (Botanical Garden)-APRIL 2011						
	BUILDING / STRUCTURE			**ROADS & PAVEMENTS**		**GREEN**
Sr. No	**Number**	**Name**	**Roof Area-Sft**	**Name**	**Area-Sft**	**Area-Sft**
1	A-11	Water Tank	4791	Luqman Avenue	175314	7046822
2	C-3	IESE	37648	Other	40296	
3	H-3	MSH	9376		4007	
8	Z-2	SCME	18790			
	TOTAL		**70605**		**219617**	**7046822**
	In Square meters		**6559**		**20402**	**654650**

Total Area of Zone 5 is **681611 Sqm**